Economics Education and Research Consortium
Working Paper Series

Price Discovery and Market Information in the Transition Economy of Russia

A Laboratory Study

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Working Paper No 01/14

This project (No 99-216) was supported
by the Economics Education and Research Consortium

Research area: **Enterprises and Product Markets**

JEL Classification: D80, C78, C90

YAKUNINA A.V., MENKHAUS D.J. Price Discovery and Market Information in the Transition Economy of Russia: A Laboratory Study. —
Moscow: EERC, 2002. — pp 1 – 72.

Using laboratory experiments we study how the levels of prices, quantities traded, and earnings are affected in decentralized as compared with centralized trading in the case of spot delivery; and if market price reports can improve efficiency in decentralized trading. Results indicate that sellers are in a weaker bargaining position than buyers in decentralized spot trading, due to advance production and the associated risk of inventory loss. Additionally provided price information does not improve the bargaining position of sellers and, in some cases, can worsen market efficiency as well as the distribution of earnings between sellers and buyers.

Keywords: Russia, information, private negotiation, experiments.

Acknowledgements. The authors are especially thankful to Owen Phillips for his advice and recommendations. The paper also benefited from the valuable comments of Richard Ericson, Revold Entov, Michael Alexeev, and Mark Schaffer. Technical support provided by Vasily Bashmakov and Alexander Davydov made it possible to conduct experiments.

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CONTENTS

NON-TECHNICAL SUMMARY

One purpose of this paper is to understand how such characteristics as decentralized trading and spot delivery affect market price, quantity traded, and buyer and seller surpluses. Another purpose is to test if the market outcomes would become closer to those of the competitive equilibrium if the decentralized spot market participants are provided with additional information about market prices. A set of laboratory experiments was designed to investigate these issues.

We have observed that decentralized trading is becoming more popular. As an example, the Russian food system today can be characterized in general as a decentralized market, where prices are discovered through private bilateral negotiation. This is contrasted with centralized auction trading in which price is discovered through the interaction of many buyers and/or sellers. In a centralized auction market, all bids are made in the presence of all potential traders and anyone may accept any bid. In private negotiation, a single buyer and seller find each price bilaterally, and third parties normally are unaware of the bids and trade prices. Therefore, decentralized markets are much less information rich than centralized methods of exchange.

There also is a "matching" problem in private negotiation trading that is not present in auction trading. A bargaining pair may be unable to make an efficient trade because the buyer values are lower than the seller costs. At the same time, in the market there could exist other potential trading partners with whom there could be more efficient trades, if the matches were formed properly. In essence, there is less competition in private negotiation trading as compared to auction trading.

Another important characteristic of the Russian food market is that the final price in a contract is typically established at the time of delivery, *i.e.*, when the good is already produced (spot delivery). In this case the producer faces an inventory loss risk. This risk is present because many agricultural products are perishable, and if a producer is unable to sell production, the production cost is lost.

Previous research suggests that the strong competitive nature of centralized markets allows sellers to be compensated for the inventory loss risk by decreasing quantity produced. The market reacts and price increases, as a result of the reduced quantity. In this paper we show that market outcomes are different when advance production is combined with decentralized trading. In the case of a finite number of possible

trading matches, the inventory loss risk throws market power to the buyer. Seller earnings are reduced in this market setting, as the price is established at a level to cover the production cost, and the quantity supplied to the market decreases. This is a source of market inefficiency.

It is a common point of view that both market efficiency and producer earnings in decentralized trading could be increased through providing agricultural producers more information about market prices. We studied four information treatments in the laboratory private negotiation setting: (1) agents had only market information which they learned by themselves over the repeated trading cycles; (2) average price from trades in the previous trading cycle was additionally provided to agents before a production decision; (3) average price from the previous trading cycle of the centralized market with the same supply and demand schedules was additionally provided to agents before a production decision; and (4) price was reported for all trades as they occurred during a trading cycle.

The experiment results suggest that providing additional information about prices in a decentralized market with spot delivery, far from improving sellers' earnings, tends to make them worse! Public information seems to work more in favor of those who have stronger bargaining positions, *i.e.*, in favor of buyers. Seller earnings in each of the treatments with additionally provided market information were lower than in the treatment when the agents had only information they learned by themselves.

In the paper we demonstrate that these results are to be expected. Analyses of the laboratory data suggest that sellers adjusted their production decision according to the additionally provided price information, so that the reported price would be a little higher than their marginal production cost. Besides, both sellers and buyers used the information to form their price expectations in the trading cycles that followed. Buyer market power resulted in reported prices being considered as the upper, rather than average price, level in the trading cycles.

When market agents are provided with average price (which in the decentralized spot market tends to be near the monopsony level), a risk averse seller reduces his/her production relative to the monopsony level price, in order to avoid the situation in which the marginal unit has to be sold at a loss. A buyer, however, maximizing his/her profit responds to the quantity reduction by a further decrease in price (goes down the cost schedule). As a result, less quantity is sold and for a lower price, hence, seller earnings decrease.

On the other hand, when the reported prices are high (*e.g.*, prices reported from the competitive centralized market) and a producer responds with increased production, the producer loses again. A buyer does not have an incentive to buy the quantity that exceeds the optimum monopsony level at a price that would cover the production costs because the buyer would not benefit from that decision. Instead, the buyer uses his/her market power and forces the seller to accept a lower price. The seller will do this because he/she would lose all production costs for the extra units, if the lower price offered by the buyer was not accepted. The producer-seller loses again. Thus, we conclude that the market price information as provided in our experiments could hardly make producers better off and, since quantity produced could be decreased, market efficiency would be reduced.

1. INTRODUCTION

The methods of exchange that evolve in the infant market economy of Russia provide differing structures and price discovery mechanisms through which individual choice is expressed (Yakunina *et al*., 1998). We have observed in the Russian food system, as an example, the evolution of such forms of coordination as vertical integration, business alliances, and different contracts. Wholesale food markets have been established in many regions. However, open centralized or auction trading of agricultural products that is traditional in Western countries has not developed in Russia. In general, the Russian food system can be characterized as a more decentralized than centralized market. Price in a decentralized market is not discovered through the interaction of many buyers and sellers as in auction exchange. Instead, it is discovered primarily through private, bilateral negotiation[1]. Private negotiation, including barter, is becoming a common and important trading institution in other countries as well. In the U.S. agriculture, for example, private negotiation trading is replacing auction trading.

In typical auction trading, exchange of an agricultural good usually requires production before negotiation for price (so called spot delivery), while contracts and private negotiations for price may often propose production-to-demand (forward delivery). Forward contracting has the potential of reducing a producer's risk of holding unsold units and can guarantee the revenue of goods delivered in the future. Processors, by forward contracting, also may reduce risk involving quality control and the interrupted flow of inputs. Nevertheless, uncertainties currently faced by Russian firms have resulted in terms of trade in a contract, particularly price, being mostly established at the time of delivery. Forward and spot trading, as two alternative methods of product delivery, influence price discovery (Phillips, Menkhaus and Krogmeier, 2001). It also is true that the influence of delivery method on price discovery may be different depending upon the trading institutions. Exchange institutions such as a non-strategic, competitive market provide structure for individuals' choices and thus will induce a collective behavior that differs notably from the behavior of an arbitrary set of disjointed individuals (Crocker, Shogren and Turner, 1998).

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[1] This was confirmed through interviews with businessmen in the food sector of the Saratov region.

An important aspect of a trading institution is the information it generates for the participants. Centralized (auction) trading typically is characterized by offers and/or bids being made in the presence of all interested parties and involved traders may accept or counter bids and offers. In decentralized trading (private negotiation), each price is discovered bilaterally by a single buyer and seller. The negotiation process is usually conducted with little formality and information coming from the negotiation process is restricted to the buyer and the seller. Third parties normally are unaware of the bids and trade prices (Buccola, 1985). There are thus relatively severe restrictions on information dissemination in this market institution, as compared to auctions. There also is a "matching" problem in private negotiation trading that is not present in auction trading. A bargaining pair may be unable to trade or only make inefficient trades because differences between buyer values and seller costs are small or negative. In essence, there is less competition in private negotiation trading as compared to auction trading. The institutional structure of privately negotiated exchange likely impacts the outcome of the market and its efficiency, and compared to an auction environment, it is less efficient.[2]

The efficiency of decentralized trading could be improved by having government or/and private agencies gather transaction price information and disseminate it among the market participants. In the U.S., as an example, recent Mandatory Price Reporting legislation requires the particulars of large negotiated transactions to be made public. Besides, in a country where open (centralized) markets exist, price information from these markets can be used by those who transact through private negotiations. Smith (1994), however, suggests that providing agents with more information, far from improving market competitiveness, can make it worse. Better-informed agents, perhaps through the provision of public information, are unable to ignore such information, even when it is advantageous to do so. Some types of information in spot markets, as we show in this paper, may increase the bargaining power of buyers as a group. The information creates market power that reduces market efficiency. This situation of more information not always being better for the market has been referred to as the "curse of knowledge" (Camerer, Loewenstein and Weber, 1989).

The purpose of this research is to investigate the impacts of alternative market information scenarios on market outcomes when there is private negotiation in spot delivery markets. Specifically, laboratory markets are

[2] We consider a market as an efficient one if a sum of buyer and seller surpluses is maximized given the relative demand and supply schedules.

used to assess market outcomes (prices, trades, and earnings) in double auction (centralized) and private negotiation (decentralized) trading. Alternative market information scenarios include (1) no information other than that which is naturally generated, then (2) average price from trades in the previous production cycle is additionally provided, (3) average price from the previous production cycle of the centralized (double auction) trading is additionally provided, and (4) price is reported for all trades as they occur during a production cycle. Reporting all trade prices as they occur is intended to more closely mimic an auction trading institution in which all trade prices are known to agents. The additional information treatments (2) – (4) assume that a number of bilateral negotiations are taking place simultaneously in a trading cycle. We focus on spot delivery, *i.e*. advance-production, because it dominates in agriculture and in many business-to-business transactions in Russia.

2. ECONOMIC THEORY AND PREVIOUS RESEARCH

The simple competitive supply and demand analysis has been an effective means of predicting outcomes in auction markets. Agents, myopically acting to maximize gains through bids and/or offers, and unaware of broader market forces, move toward total sales and an average price that is established by the intersection of the market supply and demand schedules. A double auction trading mechanism has been recognized by experimentalists as the market type where the predictions of the competitive model appear to be robust to a wide variety of supply and demand configurations, to very harsh restrictions on the number of agents, and to conditions regulating communications between sellers (Davis and Holt, 1993, pp.167 – 168).

An important observation about double-auction markets is that complete information regarding supply and demand arrays is not only unnecessary, but it may impede the convergence process (Smith, 1976, 1980). Smith and Williams (1982) suggested that even though cost and value information is private, the negotiating process is sufficiently symmetric that participants tend to split the available surplus in initial contracts; and the distribution of the actual surplus is affected by the relative theoretical magnitudes of consumers' and producers' surpluses. The double auction trading mechanism yields higher market efficiencies than institutions with which it has been compared (Holt, 1995).

The competitive model has been a useful tool of analysis for both forward and spot auction markets (see Appendix A1 for more formal considerations). Spot delivery carries higher opportunity costs for the seller than for buyers , because inventory must be held and it may not be possible to hold inventories across production cycles. Hence leftover stocks become a sunk cost. Phillips, Menkhaus and Krogmeier (2001) examined pricing behavior for forward and spot deliveries where the trading institution was a double auction. Results suggest a tendency for prices in spot markets to converge to a level 10% higher than prices in forward markets. Market forces take into account the added costs of advance production in spot delivery, resulting in fewer trades and higher prices relative to forward delivery. Price and quantity traded in forward delivery with auction trading are close to the predicted competitive equilibrium.

Is there such a theoretical framework that describes outcomes in privately negotiated trading? Suppose the method of trading repeatedly matches a different buyer with a different seller, and allows them to sequentially trade units at possibly different prices for a set period of time. Since one buyer confronts one seller in a transaction, bilateral market power exists. Although indeterminate in its predictions of prices and quantities, the simple textbook model of bilateral monopoly provides some guidance for market outcomes in our spot delivery and forward delivery experiments. Given a downward market demand and an upward marginal cost schedule there are corresponding marginal revenue and factor cost schedules. A monopoly seller restricts sales and seeks a high price determined by the intersection of marginal revenue and marginal cost. The monopsony buyer restricts sales and seeks a low price determined by the intersection of demand and the marginal factor cost schedule. The model generally predicts a sales level less than the competitive market level and a range of prices between the perfect monopsony level and the perfect monopoly level that bracket the competitive prediction.

We argue that advance production or spot delivery in bilateral trading throws market power to the buyer. Imagine sellers and buyers matched *n* times in a single production cycle. At the beginning of the cycle, sellers have made the output decision and inventory is in stock. The seller has the opportunity to sell all stock during the *n* rounds of matches with buyers in a production cycle. Inventory cannot be carried over to the next production cycle, a characteristic of perishable products, which are common in agriculture. Excess inventory thus becomes worthless at the end of the n^{th} negotiating round. In the last round the buyer has the incentive to bid and pay virtually zero for all stock. This price paid at the end means that zero should be paid in the $n - 1$ round, then for $n - 2$, and so on for all negotiating pairs. Through backward induction the predicted Nash equilibrium price therefore is zero for a single production cycle. Sellers make losses in this scenario and will not produce in future cycles; the market disappears.

The buyer in a multi-period game seeks to maximize consumer surplus. In principle the buyer can offer any price for units over a production cycle; moving up the cost schedule until consumer surplus is maximized. We shall assume there is no price discrimination and the buyer pays a uniform price. The equilibrium price therefore, occurs, we know, where marginal factor costs intersects the demand schedule. Price and quantity sold are determined as if the buyer had perfect monopsony control of the market. This is the multi-period Nash equilibrium. The result hinges on advance production delivery. It gives the buyer bidding control. Private negotiation with forward delivery restores bilateral control of the market, giving more market power to the seller, and we would predict higher prices.

Given spot delivery, can symmetric (market) information about past trades transfer surplus to the seller and move the market toward the competitive outcome? We believe the answer is no. Our reasoning goes as follows. Suppose there is information that causes sellers to produce more — they move up the market supply schedule. This has no impact on the maximum surplus buyers can extract from the market. They have no interest in buying the additional units, therefore leftover inventory increases and seller earnings decline. Suppose there is information that causes sellers to produce less. It may take time for buyers to adjust, but they will pay less for fewer units, moving down the cost schedule, in order to maximize their surplus, and seller earnings decline. Hence we argue that any information that makes sellers produce more or less in the market will adversely impact their earnings.

In actual market trading like that constructed in our computer laboratories, with several buyers and sellers, an individual agent faces a "matching risk." Late random matches may pair a buyer with a seller where one or the other may not gain from a trade. The traders cannot find a reasonably positive difference between marginal value and marginal cost. If there are n finite matches in a production cycle, valuable trading time is wasted. Hence we believe that traders have an incentive to trade early in a production cycle, and this may dilute some of the agent's market power. Buyers, wishing to avoid a later mis-match, will move the price above the monopsony level. Altogether, the impact of advance production on prices in private negotiation is our empirical question, but we have reason to believe that prices will be closer to the monopsony than the monopoly level when there is advance production.

Experiments using decentralized or private negotiations have been less common than double auctions (centralized trading) in the economics literature. Decentralized negotiations, in fact, were among the first experiments conducted (Chamberlin, 1948). Chamberlin (1948) and Hong and

Plott (1982) observed the excess-quantity outcome in experiments with negotiated prices. Holt (1995) indicates that this result is suspect because Chamberlin's subjects had no financial motivation, and Hong and Plott report only two sessions, conducted in the same week with the same group of subjects. Moreover, in the experiments conducted by Hong and Plott (1982) two parties engaged in negotiation via the telephone. The telephone market provides a convenient means to conduct private negotiation trading experiments but also contributes to reduced control, because it is difficult to monitor each phone conversation. Buccola (1985) studied pricing efficiency for forward delivery in double auction with multiple buyers and sellers and private negotiations trading. The experiments were conducted orally, and in the private negotiation experiment, just as in the auction market, transaction prices were written on a chalkboard as soon as trades were made. Mean-squared error was found to be lower in auction trading than in private negotiation trading, suggesting auctions may be more information efficient. Buccola did not consider the case when prices discovered in a private negotiation setting were effectively proprietary and not reported to agents.

The issue of information dissemination has been studied in the context of experimental asset markets (Sunder, 1995). These experiments proved that dissemination and aggregation of information through the trading mechanism alone (as opposed to conversations among traders, or news) is possible, although it is not defensible to argue that rational expectations equilibria are achieved in all market environments. Another set of asset market experiments were conducted to determine the effect of market transparency (trade and quote disclosure) on price discovery, bid-asks spreads, and market efficiency (Bloomfield and O'Hara, 1999; Flood *et al*., 1999). These studies followed the theoretical analysis of Pagano and Roell (1996) which predicted that transparency matters because patterns in trades, such as imbalances of buy or sell orders across the market, may be more easily discerned in transparent markets. This, in turn, allows market makers to learn any information from trades more quickly, and thereby set their prices more efficiently.

Laboratory experiments, however, suggest that there is a trade-off between informational and transactional efficiency. Bloomfield and O'Hara (1999) discovered that price errors decline more rapidly in the transparent markets, suggesting that transparent markets reveal information more rapidly and completely than less transparent markets. This increased efficiency is accompanied, however, by increases in opening bid-ask spreads and, to some extent, later spreads as well, which apparently is a result of reduced market-makers' incentives to compete for order flow (greater transactional inefficiency). Note that the authors use the midpoint of the market bid and ask as a proxy for the market price in each trading round. Therefore, given the higher bid-ask spread of the transparent markets, even if the midpoint of the market bid and ask is approached more rapidly, this does not necessarily mean that the bids and asks themselves (actual prices) approach the true value more rapidly. The results of a similar experimental study conducted by Flood *et al*. (1999) suggested that transparency involves lower spreads and less efficient prices.

The above discussion yields the following propositions.

Proposition 1. Private negotiation trading will restrict sales relative to the competitively determined equilibrium.

Proposition 2. In private negotiation trading, price will range between the pure monopoly and pure monopsony level. For the forward delivery, price will be close to the competitively determined equilibrium; for the spot delivery, price will be closer to the monospony level, thus, it will be reduced relative to the forward price.

Proposition 3. Providing agents with additional information about average market price from previous trade cycle or prices of all trades as they occur during a production cycle will not increase quantity traded and/or price for the spot delivery in private negotiation trading. Hence, the additional price information will not result in a higher efficiency in the private negotiation spot market.

3. LABORATORY MARKETS AND PROCEDURES

Laboratory experimental economics (Plott, 1982; Smith, 1982) was used to obtain data for the analyses. This approach is warranted because data from private negotiations are proprietary and unavailable. A laboratory method is particularly useful to study markets in Russia, where market data may not be available or accurate. This method also allows us to reduce the confounding influence of the myriad of variables present in naturally occurring markets. Laboratory markets provide for a controlled environment. By using a sufficiently simple framework, the effects resulting from a change in the trading institution, or other variable, can be isolated.

3.1. Basic Design

All trading was conducted over a computer network. Consistent with previous studies (*e.g*., Krogmeier, 1996), an experimental session consisted of 15 four and one-half-minute trading cycles. As in Noussair, Plott, and Riezman (1995) and Mestelman and Welland (1987) four buyers and four sellers participated in each laboratory market session.

Reservation values, unit costs, and earnings were denoted on a monetarily convertible currency called tokens to accommodate changes in inflation and to facilitate comparison of results. The exchange rate used in the experiments was 35 tokens = 1 ruble. At the beginning of each session, each participant was given an initial token balance (700 tokens).[3] Participants were told that they were free to keep this money plus any they earned from trading.

Buyers were privately given a table that listed the maximum reservation (resale) values for each unit purchased. Sellers were similarly provided with unit costs. Unit values and unit costs were identical for each buyer and each seller, respectively. Unit values and unit costs used in the experiments are reported in Table 1.

Table 1. Unit Values and Unit Costs (tokens).

Unit(s)	Unit Values (Buyers)	Unit Costs (Sellers)
1	130	30
2	120	40
3	110	50
4	100	60
5	90	70
6	80	80
7	70	90
8	60	100

Each buyer was allowed to purchase, one at a time, up to eight units during each trading period. The first unit purchased in each period was

[3] This initial balance was deemed necessary in our spot market experiments, since sellers must incur production costs prior to being given the opportunity to earn profit from sales. An additional concern is that the initial endowment be large enough to preclude the possibility of individual bankruptcy early in the session, particularly for sellers. In order that symmetry between buyers and sellers be maintained, the initial balance will be given to both buyers and sellers.

the highest value unit, the second purchased was the second highest value unit, and so on. Likewise, each seller was allowed to produce up to eight units and to sell produced units, one at a time, in each trading period. The first unit produced (sold) was the lowest cost unit, the second unit was the second lowest cost unit, and so on.

Earnings for a buyer on each unit purchased were equal to the redemption value of the particular unit less the price paid to the seller. Earnings for a seller on each unit sold were equal to the price received by the seller less the production cost of the particular unit. Earnings were accumulated over the sequence of trading periods and were displayed on the computer screen at the end of each trading period. At the end of the experiment session, participants were paid the cash equivalent of their earnings.

Buyers (sellers) were allowed at any time to submit bids (offers) for a single unit. Bids (offers) were submitted by typing the numerical value into the computer. The best bid (offer) was displayed on each individual's computer screen. Valid bids (offers) were made to follow an "improvement" rule, *i.e.*, the bid (offer) to be displayed to the market was required to be higher (lower) than that previously displayed as the best bid (offer). As suggested by Davis and Holt (1993, p. 41), to add an improvement rule to the double auction is a common practice. Also, following common practice, a valid bid (offer) in our experiments was not allowed to exceed (be lower) than the asking (bid) price currently displayed if one existed. A trade occurred when a best bid (offer) equaled the best offer (bid).

The control treatments in this experiment are the forward and spot centralized markets — double auction trading institutions. Test treatments are private negotiation (decentralized) forward and spot markets, without and with additional price information (market price reports) in the latter.

Fig. 1 illustrates the design of the trading cycle for each treatment. A practice session (Phase 1) was conducted after the instructions for the experiment were presented to the participants and before the actual experiment. At the end of every trading cycle, earnings were reported and recorded by experiment participants (Phase 6). Sample instructions are presented in Appendix A2. A new trading cycle then began. Each experiment session lasted from 2.5 to 3 hours.

3.2. Spot versus Forward Delivery

The spot market involved Phases 1, 3, 4, and 6. Sellers made a production decision, thereby providing units for sale in a centralized market or

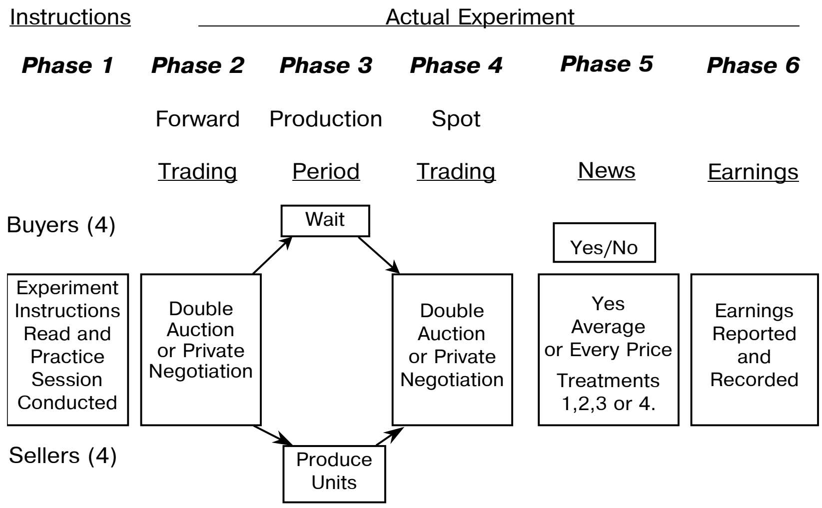

Fig. 1. Organization of Trading Cycle for Treatments.

decentralized market. The production cost associated with these units was incurred before trading began, reflecting the advance production nature of a spot market. Sellers were allowed to sell only the number of units they produced and there was no inventory carryover from one trading period to the next.[4] Buyers resell purchased units to the auctioneer at predetermined prices to make a profit on each unit.[5]

Thus, sellers in the spot market face risk of inventory loss (not being able to sell produced units and losing the cost of production) and, at the same time, they face the risk of losing potential earnings if they do not produce enough units. Buyers, however, face only the risk of losing potential earnings if sellers do not produce enough units. Therefore, in the spot experiment design sellers face higher risk. This higher seller risk, we believe, is endogenous in the case of a spot delivery. Notice, that in our design both sellers and buyers have zero fixed cost[6]. If sellers and/or buyers had a positive fixed cost, they would face the additional risk of not being able to earn profits large enough to cover the fixed cost. In our simplified design with zero fixed cost, sellers and buyers are

[4] This is characteristic of perishable commodities that are common in agricultural/food markets.

[5] There is no intermediary allowed.

[6] In fact, both buyers and sellers act like intermediaries in our experiments.

in the same position before sellers produce units. But as soon as a seller has produced units, the relative production costs become sunk costs, and the seller's bargaining position is affected.

The forward market treatments involved Phases 1, 2, 3, and 6. In this case, trading occurs before a production decision is made. Sellers were required to produce as many units as they had sold in the forward trading and buyers are required to purchase those units. Thus, there is no inventory loss risk in this setting. The forward market treatments were conducted to better understand the effects of spot delivery in both centralized and decentralized markets.

3.3. Decentralized versus Centralized Trading

Both centralized and decentralized markets could be modeled in a laboratory setting in different ways. The main feature of a centralized market that we emphasize in this study is that all bids are offered in the presence of all potential traders and anyone may accept any bid. Some centralized markets utilize an asymmetric trading institution as in English, Dutch, or sealed bid auctions. However, in this study we use a symmetric double auction institution because of its frequent use and also because of its ability to generate competitive equilibrium results in a laboratory setting. Relying on induced value theory (Smith, 1976, 1982), the values and costs used in the experiment (Table 1) constitute individual demand and supply for each trading period. When summed horizontally (over four sellers and four buyers) the aggregate supply and demand curves for the centralized (double auction) market are derived. Competitive price theory predicts an equilibrium price of 80 tokens and units traded between 20 and 24 units per period. Of course, adding risk of inventory loss in the spot delivery setting might reduce the number of units traded and increase the price relative to the competitive equilibrium.

Because decentralized markets involve much less formal rules, a great diversity of designs could be used. We chose a design for our experiments to better serve the purpose of the study. Private negotiation is a complicated process and usually involves many aspects, such as the searching and matching problem, reputation, *etc.* These effects would necessarily appear if we permitted the subjects to choose a trading partner. We are not interested in investigating these effects in this study, and our design eliminates them for the purpose of control. Buyers and sellers were randomly matched in the private negotiation treatments. In these sessions, matched pairs were given one and one-half minutes to trade and then another random match was made, for three matches during a four and one-half-minute trading session. An exception was a treatment that was aimed to test if an increase in the number of trading matches affects market outcomes (the DS5 treatment). In this treatment the number of matches was increased to five, one minute each. The trading procedures in the private negotiation sessions followed those of the double auction except for the number of traders — in private negotiation only one seller and one buyer pair was involved in the double auction.

Thus, trading in the private negotiation setting in our design is a sequence of bilateral monopoly trading. Fig. 2 illustrates the bilateral monopoly solution for the unit values and unit costs used in our experiments. The predicted quantity traded for the bilateral monopoly case is four units for both a buyer and a seller, as compared to the competitive quantity of between five and six units for each participant. Aggregating units traded for four buyers and four sellers yields a predicted market quantity of 16 units for the bilateral market setting. Any added risks for either the buyer or seller might be expected to further reduce units traded, as compared to the competitive equilibrium. This, for example, might include the risk of advance production for the seller. The predicted bilateral monopoly price is in the range of 60 to 100 tokens; the monopsony price is 60 tokens. For the spot trading, we are predicting prices close to this level, rather than the monopoly price of 100 tokens, or even the competitive auction price of 80 tokens.

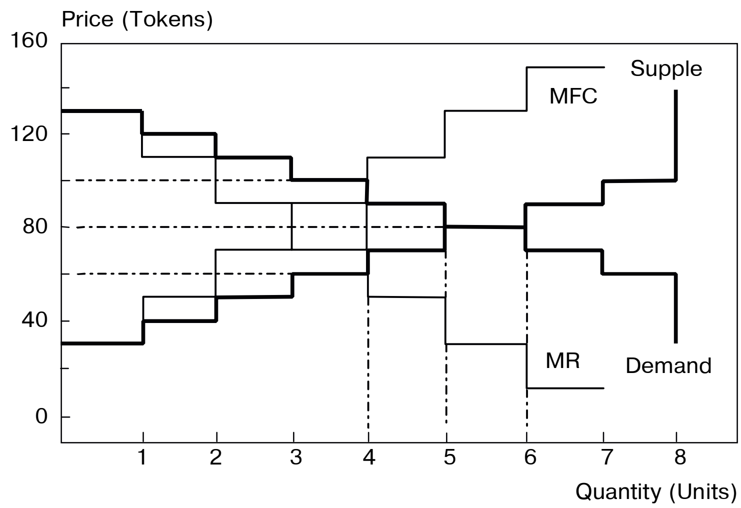

Fig. 2. Bilateral Monopoly Model.

3.4. Market Information

The type of information that is additionally supplied to market participants raises the issue of market transparency. Bloomfield and O'Hara (1999) suggest that defining a transparent market is problematic, even though the Securities and Exchange Commission in the U.S. considers market transparency as the real time, public dissemination of trade and quote information. According to Bloomfield and O'Hara, publicly available trade and quote data are certainly characteristics of transparent markets, but so too may be data on trade size, trader identity, order type, and the size and distribution of any limit orders (p. 9).

The above authors investigated transparency effects in financial markets. These markets are usually more restricted in terms of trade, as compared to agricultural commodity markets. In the real world, however, one can hardly require traders to necessarily report their quote and price information for every transaction to increase the degree of transparency in agricultural markets. A more realistic scenario would be for the government or/and private agencies to gather price information for, say, a week or a month through some survey and to inform the agents about the average price level in the market. In developed economies, *e.g.*, in the U.S., information from an existing centralized market is often used by decentralized traders as the market price level. Often times this information serves as a base for a formula pricing in individual negotiations (Rhodes, 1993, p. 219).

The above issues were primary considerations for the design of the market price reports treatments in decentralized spot trading. Four types of a market price reports were investigated in this study (Phase 5 in Fig. 1):

- Information Treatment 1 — No market information is reported. We refer to this as the Decentralized Spot treatment (DS);
- Information Treatment 2 — After the trading was completed, we provided agents with the average price from all trades, which we refer to as the market price, in the cycle. This is labeled as the Decentralized Spot/Decentralized Information (DS/DI) treatment;
- Information Treatment 3 — After the trading was completed, we provided agents with the average price for the three replications from the trading cycle of the control treatment (spot centralized trading). For reference the label is the Decentralized Spot/Centralized Information (DS/CI) treatment;
- Information Treatment 4 — Every trade price was displayed to all participants in the session immediately after the trade had been made. The treatment is labeled the Decentralized Spot/Trade Price (DS/TP).

In the Information Treatments 2 and 3, the information was announced aloud, and all participants were required to record it. The participants could use this information to make production/procurement decisions and to negotiate price in the next trading cycle. In the Information Treatment 4, the participants could see every trade price on their computer screens immediately after the trade was made, and the information was saved and available for the participants during the entire trading cycle.

3.5. Buyer and Seller Expected Prices

An interesting issue that relates to the effects of information is how market news reports influence buyers' and sellers' price expectations. In an attempt to understand these effects we conducted additional replications of the decentralized spot trading (Information Treatment 1) and also decentralized spot trading with a market price reports (Information Treatment 2). In these replications we required the participants to privately indicate their expected prices for a trading period before trading began, which they also recorded.

4. EVIDENCE FROM LABORATORY MARKETS

Laboratory markets incorporating alternative trading institutions and methods of delivery yield data for quantities traded, trade prices, and earnings for buyers and sellers. The data are initially analyzed graphically (Appendix A3). Graphical presentations provide general impressions of the behavior of experimental data and are a useful first step in the analysis (Davis and Holt, 1993). A more complete description of the characteristics of the data generated in the experiments conducted in this study is provided by means of a convergence model (Ashenfelter *et al*., 1992; Noussair, Plott, and Reizman, 1995).

The experimental data generated over several time periods, pooled with cross section data (for example across the treatments described in the presentation of the experimental design) may be serially correlated and heteroscedastic. Data also may be contemporaneously correlated between cross sections due to the same unit values/costs being used, as an example, between and among alternative treatments. We estimate variations of the following general convergence model.

$$P_{it} = B_0 \frac{t-1}{t} + B_1 \frac{1}{t} + \sum_{j=1}^{i-1} a_j D_j \frac{t-1}{t} + \sum_{j=1}^{i-1} \Gamma_j D_j \frac{1}{t} + u_{it}, \tag{1}$$

where

P_{it} — average sale price (or units traded or earnings) across all replications and all trades for each of t cycles in cross section (treatment) i;

B_0 — the predicted asymptote of the dependent variable for the base category (D_j);

B_1 — predicted starting level of the data;

t — trading cycles — 1, …, 15;

i — treatment (1, …, 9) competitive norm (base), centralized forward, decentralized forward, centralized spot, decentralized spot, decentralized spot /decentralized information, and decentralized spot / centralized information, decentralized spot / trade prices, and decentralized spot with 5 matches;

D_j — dummy variable representing treatment; the competitive norm is the base; and

u_{it} — error term.

The asymptote values are of primary interest in this study, particularly how they differ across treatments. Sale prices (and units traded and earnings) for a treatment are averaged across the replications to reduce the influence of individual agents.

The Parks (1967) method is used to estimate the model. This is an autoregressive model in which the random errors u_{it}, $i = 1, 2, \ldots, N$, $t = 1, 2, \ldots, T$, have the structures (SAS, 1993).

$E\,(u_{it}^2) = \sigma_{ii}$ (heteroscedasticity).

$E\,(u_{it}) = \sigma_{ji}$ (contemporaneously correlated).

$u_{it} = \rho_i\, u_{i,\,t-1} + \varepsilon_{it}$ (autoregression).

The Parks method assumes a first-order autoregressive error structure with contemporaneous correlation between cross sections. The covariance matrix is obtained by a two-stage procedure leading to the estimation of model regression parameters by generalized least squares. (See SAS, pp. 882 – 884, for details of this estimation method.) The use of the Parks method allows us to take account of the unique statistical problems resulting from the panel data sets that consist of time series observations on each of the several cross-sectional units generated in our experiments. The method requires the number of observations per cross section to be balanced and the number of time series observations to be greater than the number of cross-sections. The latter constraint precluded pooling, *e.g.*, buyer and seller earnings for analysis in one equation. Differences were used as the dependent variable in the convergence model in this case. The estimated convergence model and related statistical tests are reported in Appendix A4.

In the following, the results of the twenty-nine experimental sessions are summarized and analyzed:[7]

- centralized forward market (CF) — 3 replications;
- decentralized forward market (DF) — 3 replications;
- centralized spot market (CS) — 3 replications;
- decentralized spot market (DS) — 3 replications + 3 replications with participants privately indicating their expected prices;
- decentralized spot market with additionally provided information about previous period average price in the same replication of the decentralized market (DS/DI) — 3 replications + 3 replications with participants privately indicating their expected prices;
- decentralized spot market with additionally provided information about previous period average price in the three replications of the centralized spot market (DS/CI) — 2 replications;
- decentralized spot market with additionally provided immediate information about every trade price in the same replication of the decentralized spot market (DS/TP) — 3 replications;
- decentralized spot market with five available trading matches in a trading cycle (DS5) — 3 replications.

The experiments generated data for several market outcomes — prices, quantities produced and traded, total earnings, and seller and buyer earnings. The results are reported focusing on three major issues — Decentralized and Centralized Trading with Forward and Spot Deliveries, Decentralized Spot Trading with Market Price Reports, and Decentralized Spot Trading with five, as opposed to three, available trading matches in a trading cycle.

4.1. Decentralized and Centralized Trading with Forward and Spot Deliveries

Average trade prices in centralized and decentralized trading with both forward and spot deliveries are presented in Fig. 4 in Appendix A3.

[7] The data from the additional replications in which expected prices were requested from agents in the DS and DS/DI treatments were pooled with data from the initial replications in these respective treatments. A test of mean prices and quantities traded (Wilcoxon non-parametric test) from the last five periods across replications for each respective treatment showed no statistical differences.

Prices in centralized trading, whether forward or spot delivery (CF and CS), and also prices in decentralized forward trading (DF) tend toward the predicted competitive equilibrium of 80 tokens. The average prices for the latter periods are 77.70, 82.28, and 80.39 tokens for CF, CS, and DF, respectively (Table 2). Prices in the decentralized spot market (DS) are noticeably lower (74.33 tokens), as compared with prices in centralized trading (Fig. 4 and Table 2). Prices in decentralized forward and spot trading exhibit relatively more variability than in centralized trading. The most variable prices are in the decentralized spot trading.[8]

Table 2. Averages and Variances for Selected Treatments and Market Outcomes (Periods 11 – 15).

	Price		Quantity		Total Earnings	
	Av.	Var.	Av.	Var.	Av.	Var.
CF*	77.70	9.09	21.73	0.78	1189.00	220.95
DF	80.39	43.34	16.27	1.07	1050.67	1920.95
CS	82.28	6.16	21.33	0.67	1186.67	409.52
DS	74.33	46.94	16.67	6.23	1061.00	5898.97

	Seller Earnings		Buyer Earnings	
	Av.	Var.	Av.	Var.
CF*	137.42	259.47	159.92	176.08
DF	132.88	802.16	129.75	902.61
CS	158.73	235.66	137.93	179.06
DS	107.37	1327.19	157.88	913.39

* CF and CS — centralized forward and spot markets, respectively;
DF and DS — decentralized forward and spot market, respectively.

There are considerable differences in quantities traded between centralized and decentralized trading (Fig. 5). Quantities sold/purchased in centralized forward and spot trading average 21.73 and 21.33, respectively, for the last five periods (Table 2). These levels are in the predicted competitive equilibrium range (20 to 24 units). Quantities traded in the

[8] We ran six replications of this treatment as compared to three replications of any other treatment in the Table 2, but the price variance in the DS treatment is still the highest, although it approached the price variance in the DF treatment

decentralized markets are lower than those in the centralized market and average about 16 units for both forward and spot deliveries. Thus, in latter periods, agents each traded about four units, which is consistent with the prediction from the bilateral monopoly model (Fig. 2). Quantity traded in decentralized spot trading is much more variable than in any other trading considered.

Lower quantities traded in the decentralized markets reduces total earnings, as compared to the total earnings in centralized trading (Fig. 6). Earnings in the centralized forward and spot markets are about 99 percent of the total possible earnings in the competitive model (1200 tokens), as compared to about 88 percent in the DF and DS markets. Variability in total earnings is greater in decentralized trading than in centralized trading, and total earnings in decentralized spot trading is three times more variable than in decentralized forward trading (Table 2).

The difference in the distribution of earnings between sellers and buyers is greatest in the case of the decentralized spot market (Figs 7 and 8 and Table 2). The variability in earnings for both sellers and buyers also is greatest in this treatment, as compared with the CF, CS and DF markets. Clearly, there is a significant impact on the distribution of earnings associated with decentralized trading and spot delivery.

The impacts of alternative trading and delivery mechanisms can be assessed more definitively through the use of results from the convergence model described earlier (Table A4.1 in Appendix A4). Estimated price asymptotes for the CF, DF, CS, and DS markets are 76.668, 80.920, 81.399, and 74.459, respectively (Table 3). The price asymptotes in each of the CF, DF, and DS treatment are significantly different ($\alpha = 0.05$) from the base competitive model price of 80 tokens, and the estimated asymptote for DS exhibits the greatest divergence (Table A4.1 in Appendix A4). Paired differences in convergence price levels in each case are significantly different, except estimated asymptotes in DF and CS markets (Table 3). Comparing the predicted starting values with the predicted asymptotes, we see that prices in these treatments do not exhibit an obvious trend, either upward or downward.

Estimated asymptotes for quantity traded in the markets under consideration are 22.605 for CF, 21.316 for CS, 16.330 for DF, and 16.416 for DS. The quantity asymptotes in the DF and DS markets are significantly (α=0.05) lower than the base competitive norm of 20 units (Table A4.1). The difference in estimated asymptotes for quantity traded in the CF and CS markets is significant ($\alpha = 0.05$). Also significant are the differences in asymptotes for CF and DF and for the CS and DS markets (Table 3). The difference in the estimated asymptotes for the DF and DS markets is not statistically significant. The estimated asymptote (22.605) was considerably higher than the estimated starting value (14.824) for the centralized forward market, *i.e.*, the CF quantity traded demonstrated an upward trend. There were no obvious upward or downward trends in quantity over periods in other treatments.

Table 3. Estimated Asymptotes and Starting Values for Selected Treatments.

Variable	Centralized Forward (CF)		Decentralized Forward (DF)	
	Asymptote	Starting value	Asymptote	Starting value
Price	76.668 a*	81.218	80.920 b	82.833
Quantity Traded	22.605 a	14.824	16.330 b	15.842
Total Earning	1207.265 a	1008.791	1055.257 b	1061.230
Buyer Earnings	166.320 a	118.593	128.878 b	121.610
Seller Earnings	136.002 a	131.553	135.045 a	143.084
Buyer/Seller Earnings Difference	31.533 a	−18.625	−6.137 b	−21.894
Variable	**Centralized Spot (CS)**		**Decentralized Spot (DS)**	
	Asymptote	Starting value	Asymptote	Starting value
Price	81.399 b	78.708	74.459 d	73.835
Quantity Traded	21.316 c	21.922	16.416 b	16.801
Total Earning	1183.159 c	1171.344	1050.440 b	968.600
Buyer Earnings	141.609 c	159.302	153.653 d	152.578
Seller Earnings	155.282	132.584	108.918	88.352
Buyer/Seller Earnings Difference	−12.128 b	18.700	43.393 a	69.429

* a,b,c,d — same letter indicates no significant difference between estimated asymptotes in the respective equations. A different letter indicates a significant difference between estimated asymptotes, $\alpha = 0.05$.

The asymptotes for total earnings are estimated as 1207.265, 1055.257, 1183.159 and 1050.440 for the CF, in DF, CS, and DS markets are significantly different from the DF, CS, and DS markets, respectively. The estimated total earnings asymptotes base competitive norm of 1200 tokens ($\alpha = 0.05$, Table A4.1). Paired differences in convergence total earnings levels are significantly different ($\alpha = 0.05$, Table 3) for each of the considered treatments except for the difference between the DS and

DF treatments. The starting value estimates are considerably lower than the estimated asymptotes in the CF and DS markets, suggesting upward trends in the convergence process for total earnings in these treatments. Thus, learning from one trading period to another obviously helped the market participants to increase their total earnings.

Buyer earnings in the CF, DF, CS, and DS converged to levels of 166.320, 128.878, 141.609, and 153.653, respectively. According to statistical tests presented in Table A4.1, the estimated asymptotes are significantly lower than the base competitive norm of 150 tokens in the DF and CS markets ($\alpha = 0.05$). The buyer earnings asymptotes in the other two treatments are not significantly different from the competitive norm. Differences in estimated asymptotes between all pairs of the selected treatments are significant ($\alpha = 0.05$, Table 3). The differences between the estimated asymptotes and starting values suggest an upward trend in the CF buyer earnings convergence level.

The estimated asymptotes for the seller earnings in the CF, DF, CS, and DS are 136.002, 135.045, 155.282, and 108.918, respectively. The asymptotes are significantly lower than the competitive norm of 150 tokens for all of the treatments but the CS treatment ($\alpha = 0.05$, Table A4.1). The DS seller earnings asymptote is associated with the lowest value, which is more than 41 tokens lower than the competitive equilibrium result. Differences in seller earnings asymptotes for any two of the selected treatments are significant, except for the CF and DF treatments (Table 3). In the centralized and decentralized spot markets (CS and DS) there are obvious upward trends in the seller earnings convergence processes.

The last set of estimated coefficients describes differences in buyer and seller earnings, *i.e.*, the distribution of earnings between buyers and sellers in the selected treatments. According to the estimated asymptotes, buyer earnings exceed seller earnings by 31.533 in the CF market, and by 43.393 in the DS market. In the DF and CS markets seller earnings exceed buyer earnings by 6.137 and 12.128, respectively. The differences in the estimated asymptotes from the competitive norm of zero tokens are significant for all but the CS treatments. Differences in asymptotes are significant for any two of the treatments, except the differences in the DF and CS asymptotes and also in the DS and CF asymptotes (Table A4.1 and Table 3). A comparison of the asymptotes and the starting values suggests that in the early periods of the CF market seller earnings exceeded buyer earnings, but this reverses in the latter periods. In contrast, in the early periods of the CS market seller earnings were lower than the buyer earnings, but in the latter periods seller earnings exceeded buyer earnings. In the decentralized forward market the seller earnings were higher than the buyer earnings, but the difference in seller and buyer earnings tends to decrease in the latter periods. Buyer earnings in the DS market were considerably higher than seller earnings, but the difference decreased in the latter periods as compared to the early periods.

The above results suggest that the competitive model is appropriate for predicting behavior in centralized trading for both forward and spot deliveries. This model accurately predicts tendencies in both price and quantity outcomes. In the centralized spot market, price converged to a higher level and quantity converged to a lower level than in the centralized forward market. The latter is consistent with the theory presented in the Appendix A1 of this paper. Market efficiencies in centralized forward and spot trading are near the optimum.

The bilateral monopoly model accurately predicts the quantities traded in decentralized forward and spot institutions. Quantity is reduced as compared to the competitive optimum (supporting Proposition 1) and this results in reduced market efficiency. In the theory section, we proposed that decentralized market price would range between the pure monopoly and pure monopsony level but would be affected by the delivery method. For the forward delivery, price would be close to the competitively determined equilibrium, while for the spot delivery, price would be lower than the forward price and tend to the monospony level. This is the result we observe from our experiments, adding evidence to support Proposition 2. There is no obvious bargaining advantage to buyers or sellers in forward delivery and price in the decentralized forward market converged to a level close to the competitive equilibrium outcome. The difference in buyer and seller earnings is rather small. But, when the seller is faced with decentralized trading in spot delivery, he/she is clearly at a disadvantage to the buyer. This is due to the risk of inventory loss associated with advance production. Evidently, the more competitive nature of bidding in the centralized spot market**,** combined with the ability of sellers to adjust production, allows sellers to compensate the advance production risk through a higher market price.

4.2. Pattern of Trades

Quantities and prices for bargaining sessions 1 – 3 across all replications and for cycles 11 – 15 of decentralized markets are reported in Table A5.1 in Appendix A5. The data show the distribution of trades and prices across bargaining sessions. Trade data reported in Table A5.1 suggest that subjects have a desire to complete trades in the initial bargaining sessions. Most (40 – 50%) of trades are made in bargaining session 1 and 70 – 75% of the trades occur in sessions 1 and 2. We use these data as evidence of a "matching risk" for buyers and sellers in latter trading sessions.

There are two sources of matching risk in private negotiation trading, and they vary depending on the method of delivery. One is the risk associated with a match in latter trading sessions that pairs a buyer and a seller in which one or the other may not gain from the trade. This risk is present in both forward and spot deliveries. The other matching risk occurs only in spot delivery and is associated with a match that pairs a buyer with a seller who has sold all units in previous sessions; the seller has no more inventory. The former risk potentially reduces the range of prices over which negotiation can occur during trading sessions 2 and 3 in our experiment. It depends on the number of units traded by the paired buyer and seller in previous sessions and as such may not exist in all buyer and seller pairings. It likely contributes to early trading, as is evident in the DF market (Table A5.1). However, average prices in each of the trading sessions in the DF market tend to be near the competitive equilibrium level and decline only about three tokens by session three, suggesting that neither buyer nor seller has a bargaining advantage over a trading cycle.

The matching risk has a stronger impact in the DS market because of advance production. We argued that price in the decentralized spot market should tend to 60 tokens, but because of matching risk could be higher. Data presented in Table A5.1 generally support these predictions. The seller, based on the price recorded for session 1, as compared to that in the DF market, seems to be more anxious to trade than the buyer. The seller is influenced by the potential loss of inventory. By bargaining session 3 there is a clear advantage to buyers in decentralized spot treatments, as reflected by the low price. However, even in session 3 the average price is 70.42 tokens instead of the monopsony level of 60 tokens. As we argued earlier, the matching risk buyers face may dilute some of their bargaining power and makes the market more competitive.

4.3. Decentralized Spot Trading with Market Information

We now will discuss the results of experiments with additionally supplied market information in decentralized spot markets. The results of these experiments are compared with those generated from the decentralized spot trading without additional market information. We have hypothesized that the additional price information will not result in a higher efficiency in the private negotiation spot market.

Fig. 9 in Appendix A3 displays average trade prices by period in the decentralized spot market institutions with market information of different types. Prices in the decentralized spot market with decentralized market price reports (DS/DI) are very close to those in the decentralized spot market without additional market information (DS). On the other hand, prices in both the decentralized market with centralized price reports (DS/CI) and decentralized spot market with all trade prices reported were consistently lower than prices in the DS treatment. Averaged over the latter five periods, prices in the DS/DI, DS/CI, and DS/TP treatments are 74.81, 63.93, and 66.92 tokens, respectively (Table 4). Thus, the average price reports from the same decentralized market did not bring the prices closer to the competitive equilibrium norm of 80 tokens. At the same time, the DS/CI and DS/TP average prices were even more biased from the competitive equilibrium than the DS prices. Price variances in the DS/DI and the DS/TP treatments are higher, and price variance in the DS/CI is lower than in the DS market.

Table 4. Averages and Variances for Selected Treatments and Market Outcomes (Periods 11 – 15).

	Price		Quantity		Total Earnings	
	Av.	Var.	Av.	Var.	Av.	Var.
DS	74.33	46.94	16.67	6.23	1061.00	5898.97
DS/DI*	74.81	76.85	14.37	2.79	968.67	5701.61
DS/CI	63.93	7.64	16.40	1.16	1031.00	6276.67
DS/TP	66.92	302.3	13.47	16.98	940.667	24535.24

	Seller Earnings		Buyer Earnings	
	Av.	Var.	Av.	Var.
DS	107.37	1327.19	157.88	913.39
DS/DI*	104.20	1443.43	137.97	938.74
DS/CI	59.83	403.08	197.93	196.39
DS/TP	89.47	4496.18	145.70	1287.83

* DS/DI — decentralized spot market with average decentralized price reports (information);
DS/CI — decentralized spot market with average centralized price reports (information);
DS/TP — decentralized spot market with every trade price immediately reported.

As is the case in the decentralized spot market, quantity traded in the market with centralized price reports is very close to the bilateral monopoly prediction (Fig. 10). Average quantity traded in the latter periods of the DS/CI market is 16.40. Quantities traded in the both DS/DI and DS/TP markets were consistently lower and for the latter periods averaged 14.37 and 13.47 units, respectively. Quantity traded exhibits relatively high variability in the DS/TP market.

Similar levels of quantities traded in the DS and DS/CI markets, as expected, resulted in similar levels of total earnings (Fig. 11). Market efficiency in the latter periods of DS/CI market is 1031.00 tokens or about 86% of available surplus of 1200 tokens (Table 4). Market efficiency in the DS/DI market is lower (968.67 tokens) and is 81% of available surplus. Market efficiency in the DS/TP treatment is even lower — 940.67 tokens or 78% of available surplus. These reductions in market efficiency in the DS/DI and DS/TP markets are a result of lower quantities traded. Total earnings are characterized by high variability in each of the decentralized spot markets, with the highest variability in the DS/TP total earnings.

Average seller and buyer earnings also exhibit high variability (Figs 12 and 13). Seller earnings for the latter periods averaged 104.20, 59.83, and 89.47 tokens in the DS/DI, DS/CI, and DS/TP markets, respectively (Table 4). Thus, in both the DS/CI and DS/TP markets seller earnings are considerably lower than in DS market, while in the DS/DI market seller earnings are only slightly lower than in the DS market. Buyer earnings are considerably higher than seller earnings in each of the decentralized spot markets. In the latter periods of the DS/DI, DS/CI, and DS/TP markets buyer earnings are 137.97, 197.93, and 145.70 tokens, respectively. Note that in competitive equilibrium sellers and buyers earn 150 tokens each. Obviously, price reports affected the distribution of earnings between sellers and buyers and lowered earnings to sellers compared with the no additional information treatment.

Further, the convergence model estimations are used to better assess the impacts of market price reports and test statistical inferences. Estimated asymptotes for price in the DS/DI, DS/CI, and DS/TP markets are 73.415, 64.280, and 67.730, respectively (Table 5). These asymptotes are significantly different from the base competitive norm of 80 tokens ($\alpha = 0.05$; Table A4.1 in Appendix A4). The DS/CI and DS/TP price asymptotes are also significantly lower than the DS price asymptote ($\alpha = 0.05$), while there is no statistically significant difference in DS and DS/DI price asymptotes (Table 5). Paired differences in convergence price levels in the DS/DI, DS/CI, and DS/TP treatments are statistically significant. We do not observe obvious upward or downward trends in the price convergence in any of the DS/DI, DS/CI, or DS/TP markets.

The estimated asymptotes for the quantities traded are 14.222 for the DS/DI market, 16.121 for the DS/CI market, and 13.183 for the DS/TP market (Table 5). These three asymptotes are significantly different from the competitive norm and from each other ($\alpha = 0.05$, Tables A4.1 and 5). The asymptotes for the quantity traded in the DS/DI and DS/TP markets are also significantly different from the DS quantity traded asymptote of 16.416. The latter is not significantly different from DS/CI asymptote. A comparison of the estimated asymptotes with the estimated starting values indicates downward trends in the convergence of the DS/CI average quantity traded (from 18.823 to 16.121) and the DS/TP quantity traded (from 17.361 to 13.183).

Table 5. Estimated Asymptotes and Starting Values for Selected Treatments.

Variable	Decentralized Spot (DS)		DS/DI	
	Asymptote	Starting value	Asymptote	Starting value
Price	74.459 a*	73.835	73.415 a	72.267
Quantity Traded	16.416 a	16.801	14.222 b	14.971
Total Earning	1050.440 a	968.600	967.489 b	946.215
Buyer Earnings	153.653 a	152.578	140.106 b	155.408
Seller Earnings	108.918 a	88.352	100.270 b	87.358
Buyer/Seller Earnings Difference	43.393 a	69.429	41.927 a	57.930
Variable	**DS/CI**		**DS/TP**	
	Asymptote	Starting value	Asymptote	Starting value
Price	64.280 c	69.064	67.730 d	70.372
Quantity Traded	16.121 a	18.823	13.183 d	17.361
Total Earning	1024.819 a	932.266	931.047 d	1114.043
Buyer Earnings	192.593 c	191.441	142.84 b	167.513
Seller Earnings	63.213 c	45.861	89.832 d	110.294
Buyer/Seller Earnings Difference	131.520 c	138.019	52.210 a	59.097

*a, b, c, d — same letter indicates no significant difference between estimated asymptotes in the respective equations. A different letter indicates a significant difference between estimated asymptotes, $\alpha = 0.05$;

DS/DI — Decentralized Spot / Decentralized Price Reports;

DS/CI — Decentralized Spot / Centralized Price Reports;

DS/TP — Decentralized Spot / All Trade Prices Reported.

Total earnings converged to 967.489 in the DS/DI market, to 1024.819 in the DS/CI market, and to 931.047 in the DS/TP market, according to the estimated asymptotes (Table 5). Each of the three asymptotes are significantly different from the base competitive norm ($\alpha = 0.05$; Table A4.1). The differences in these three asymptotes and also in the DS/DI and DS asymptotes and in the DS/TP and DS asymptotes are significant (Table 5). There is no significant difference in estimated asymptotes for the total earnings in the DS and DS/CI markets. Total earnings convergence in the DS/CI market occurred from below (from 932.266 to 1024.819), similar to that in the DS market. There is a downward trend in the total earnings convergence in the DS/TP market (from 1114.043 to 931.047).

Estimated asymptotes for buyer earnings are 140.106, 192.593, and 142.84 in the DS/DI, DS/CI, and DS/TP markets, respectively (Table 5). The difference in any of the asymptotes and both the competitive norm and the DS asymptote is significant ($\alpha = 0.05$; Table A4.1 and Table 5). Also the DS/CI buyer earnings asymptote is significantly different from both the DS/DI and the DS/TP buyer earnings. The latter two are not significantly different from each other. There is no significant difference in the DS/DI and DS/TP buyer earnings estimated asymptotes. Buyer earnings in the DS/DI and DS/TP markets demonstrate a downward trend (from 155.408 to 140.408, and from 167.513 to 142.84, respectively).

The estimated asymptote for seller earnings in the DS/DI treatment is 100.270, in DS/CI is 63.213, in DS/TP is 89.832 (Table 5). The paired differences in these asymptotes is significant ($\alpha = 0.05$). Also each of these asymptotes is significantly different from the competitive norm and from the DS asymptote ($\alpha = 0.05$, Table 5 and Table A4.1). According to results presented in Table 5, seller earnings in the DS/DI and DS/CI treatments converged from below, and in the DS/TP treatment seller earnings converged from above. But the graphical presentation in Fig. 12 does not demonstrate an obvious trend in any of these treatments.

According to the estimated asymptotes, buyer earnings exceed seller earnings by 41.927 in the DS/DI market, by 131.520 in the DS/CI market, and by 52.210 in the DS/TP market (Table 5). These asymptotes are significantly different from the competitive norm ($\alpha = 0.05$; Table A4.1). The DS/CI asymptote is also significantly different from the DS and DS/DI asymptotes. The DS/DI and DS/TP asymptotes are not significantly different from each other and the DS asymptote (Table 5). Comparisons with the starting values suggest that the difference in the buyer/seller earnings decreased in the DS/DI market from 57.930 to 41.927, but this difference was relatively stable in the DS/CI and DS/TP markets.

The above analyses suggest that additionally provided price information (DS/DI — average market price from the previous trading period of the same replication; DS/CI — average market price from the previous period of the three replications of the centralized trading; DS/TP — all trade price reported from the same period of the same replication) can impede market efficiency or at best, does not improve market efficiency in decentralized spot markets. Market efficiency, in fact, decreased in the DS/DI and DS/TP markets, as compared to decentralized trading with spot delivery without price reports. Thus, the results of our experiments support our Proposition 3. Moreover, in the DS/CI and DS/TP treatments the price decreased and moved further away from the competitive equilibrium, and the distribution of earnings between buyers and sellers moved more in favor of the buyers, at the expense of the sellers. Quantities traded in the DS and DS/CI markets follow those predicted by the bilateral monopoly model, but are lower than the predicted 16 units in the DS/DI and DS/TP markets.

4.4. How Do Agents Use Market Information?

An important aspect of laboratory markets is learning. The information gathered by agents in early periods contribute to the observed levels of convergence in, *e.g.*, price in latter periods. The information flow that contributes to learning is attributable to the bid and ask values, which are made during the bidding processes in alternative trading institutions, and the resulting earnings of participants in the experiment. Successful behavior becomes more prevalent not only because market forces select against unsuccessful behavior in our experiments, but also because agents imitate successful behavior. Learning, in fact, may be the best available justification for the Nash equilibrium (Mailath, 1998). The nature of the trading institution itself provides information that is available to agents. Bids and offers are common knowledge to all traders in the centralized trading institution, but are private to the individual buyer and seller in bilateral trading. Another source of information flow is the additionally provided market information in the respective treatments in our experiments.

Information about average price could be used by both sellers and buyers to decide what price level would be sufficient to make a trade. It could be supposed that agents would consider the average reported price as some kind of "a fair price level", and they would then be willing to make trades at that price. In this case, price variance within a replication would be lower in the information treatments than in the treatment with no price reports. However, the data generated in the experiments can hardly support this supposition (Table 6.1 in Appendix A6). Decentralized trading results in prices that are highly variable and additional information of any type considered in our experiments does not seem to reduce this variability. However, each agent could use the additionally provided information to follow his/her strategy based on his/her risk preferences, bargaining abilities, and the like. This strategy could incorporate some formula pricing with the reported average price being the base. High price variances then could be explained by differences in individual agents.

In replications 4 to 6 of the DS and DS/DI treatments we asked the participants to privately indicate their expected prices in the beginning of a trading cycle to better understand how price reports influenced an agent's behavior. Expected buyer and seller prices per period averaged for the three replications of the DS and DS/DI markets are displayed in the Figs 14 and 15 in Appendix A3. The expected price information was analyzed to assess the impacts of average decentralized price reports on average trade prices and expected buyer/seller prices. The Parks method was used to estimate the models (Appendix A4, Table A4.2). The estimated coefficients suggest that trade price as well as both expected seller and buyer prices tend to be lower when average market price is reported to the participants. The estimated coefficient for the DS/DI treatment dummy variable is −40.101 in the trade price model, −26.227 in the seller expected price model, and −40.874 in the buyer expected price model (statistically significant, $\alpha = 0.05$). Another result suggesting that average price reports were used by the participants to form their expectations and to negotiate a price is that the effects of the previous period price on trade prices, as well as on both seller and buyer expected prices, are higher in the decentralized spot market when market price is reported to the participants. The estimated coefficient for the previous period price times the DS/DI treatment dummy variable is 1.058 in the trade price model, 0.307 in the seller expected price model, and 0.426 in the buyer expected price model (statistically significant, $\alpha = 0.05$).

Also, information about average price was used by a seller to decide on how many units to produce. The upward individual cost step function (Table 1) suggests that it could be risky to produce those units for which production costs are higher than the reported average price. Fig. 16 in Appendix A3 displays the average quantity produced by a seller in each trading cycle of the decentralized spot market treatments. Average quantity produced by a seller in the latter periods of the decentralized spot market with no information (DS) was 4.34, *i.e.*, 4 to 5 units for a seller. In the market with decentralized average price reports (DS/DI), average quantity produced by a seller was consistently lower. In the latter periods of this market, a seller produced 3 to 4 units (average was 3.79). Average price in the latter periods of this market was 74.81 tokens (Table 4). This price was sufficiently high to sell at a positive profit up to 5 units (Table 1). But the 5th unit would likely bring only a little marginal profit, and a seller may not wish to take the risk of possible losses given the little possible profit from the marginal unit.

In the market with centralized average price reports (DS/CI), a seller produced on average 4.30 units, *i.e.*, 4 or 5 units in this market setting. Average price in the latter periods was 63.93 tokens, *i.e.*, sufficiently high to produce and sell at a positive profit only four units. To produce the 5th unit was quite risky. At the same time, average price in the latter periods of the centralized spot market (price reported in the DS/CI market) was 82.28 tokens (Table 2). This price would be sufficiently high to produce up to 6 units. It seems that the sellers were using the reported price to make their production decisions, although they faced difficulties selling the last unit at a profit. The higher reported market price appeared to prompt slightly higher production.

In the latter periods of the DS/TP market a seller produced on average 3.47 units, *i.e.*, 3 or 4 units for a seller. The average price for the latter periods in this treatment was 66.92 (Table 4), therefore, it was just sufficient to produce and sell at a profit up to 4 units (Table 1).

Thus, we argue that the price reports were used by sellers to adjust their production decisions. But, the lower quantities produced and traded in both the DS/DI and DS/TP treatments, as compared to the DS treatment, did not result in higher prices. In fact, price went down in the DS/TP markets as compared with the DS price. The DS/CI price also was lower than the DS price. This supports the argument made earlier that in the case of private negotiation any additional information that induces a seller to produce less or more only decreases the seller's earnings or, at least, does not increase it. Buyers do not have any incentive to buy more units for a higher price than the DS price. When additional information induces less production, a buyer may go down the cost schedule and pay even less than when more units are supplied. Note that the lowest quantity traded in the DS/TP market was accompanied by a relatively low price (Table 5). When additionally provided information induces more production than a reasonable level for a risk averse producer given the average decentralized price (as in the DS/CI treatment), a buyer agrees to buy the additional units only for a lower price and, as a result, average price decreases.

Moreover, because of the relatively weak bargaining position of the sellers in the spot decentralized market, the reported price level is more likely considered as the upper boundary of the price interval. Therefore, when a reported price is relatively low the sellers seem to be more willing to accept low bids from the buyers, while the buyers seem to become even more difficult bargainers.

Besides, additionally supplied information seems to provide yet another increased negotiation advantage to buyers. Recall that in the DS/TP treatment quantity traded was one unit less and price was almost six tokens less than in the DS/DI treatment. In both treatments the agents received price information from the replication they participated in; average price from trades in the previous production cycle was additionally provided in the DS/DI treatment and, in the DS/TP treatment price was reported for all trades as they occur during a production cycle. Therefore, in the DS/TP treatment the agents implicitly received information about quantity traded in addition to the price information. Information about quantity traded allows buyers to be more patient and mitigate the "matching risk" that they face.

Thus, public information additionally provided to the experimental market participants resulted in reduced quantity traded or/and reduced price. The public information, therefore, seems to be detrimental to improving efficiency of decentralized spot market. We consider this as an evidence of a "curse of knowledge". In the decentralized market with no price reports, the agents do not know the average price and must trust only their own experience. This is Smith's private information. The agents' profit seeking behavior may then result in a higher production and total earnings in the DS market.

4.5. Decentralized Trading with Five versus Three Matched Pairs

In all of the decentralized trading experiments discussed above there were three available bargaining matches during a trading cycle. We now consider the results of the decentralized spot market experiments when a trading cycle consists of five trading matches.

Average trade prices by period in the decentralized spot markets with three (DS) and five (DS5) available matches are displayed in Fig. 17 in Appendix A3. Prices in the DS5 treatment are consistently higher than in the DS treatment. Prices averaged over the latter five periods in the DS5 market are 78.14 tokens while in the DS market prices are 74.33 tokens (Table 6). Price variance is lower in the DS5 market despite the fewer replications in this treatment as compare to DS (three versus six replications, respectively). Nevertheless, average price in the DS5 treatment is still lower, and the variance is higher, than in the CS treatment.

Quantity traded in the DS5 market is also higher than in the DS (Fig. 18). For the latter periods, average quantity traded in the DS5 market is 17.20 as compared with 16.67 in the DS market (Table 6). The quantity variance is lower in the DS5 market. The quantity variance in this market is close that in the CS market, although the average quantity is still considerably higher in the latter.

Table 6. Averages and Variances for Selected Treatments and Market Outcomes (Periods 11 – 15).

	Price		Quantity		Total Earnings	
	Av.	Var.	Av.	Var.	Av.	Var.
CS	82.28	6.16	21.33	0.67	1186.67	409.52
DS	74.33	46.94	16.67	6.23	1061.00	5898.97
DS5*	78.14	14.88	17.20	0.60	1098.67	1598.10

	Seller Earnings		Buyer Earnings	
	Av.	Var.	Av.	Var.
CS	158.73	235.66	137.93	179.06
DS	107.37	1327.19	157.88	913.39
DS5*	131.25	189.46	143.42	231.22

* DS5 — decentralized spot market with five matched pairs.

Higher average price and average quantity resulted in increased total earnings in the DS5 treatment as compared with the DS treatment — 1198.67 and 1061.00, respectively (Table 6 and Fig. 19). Total earnings variance is reduced in the DS5 market. But the total earnings in the DS5 market is still lower, and earnings variance is higher, in the DS5 market as compared with CS.

Seller earnings are higher in the DS5 market and for the latter periods averaged 131.25 tokens as compared with 107.37 tokens in the DS market (Table 6 and Fig. 20). Again, seller earnings variance decreased in the DS5 market. But seller earnings are still higher (158.73 tokens) and its variance is still lower in the CS market as compared with DS5 market.

Buyer earnings are reduced in the DS5 market as compared with DS market — 143.42 and 157.88 tokens, respectively (Table 6 and Fig. 21). Buyer earnings variance also is reduced. The variance is even lower in the CS market, and the average buyer earnings are also lower in this market (137.93 tokens).

We again used the convergence model estimation to better assess the impacts of the increased number of available bargaining matches in the decentralized trading and spot delivery. The estimated asymptote for price in the DS5 treatment is 77.607 (Table 7). This is significantly different from the competitive norm of 80 tokens, and also is significantly different from estimated asymptotes for both DS and CS markets — 74.459 and 81.399, respectively ($\alpha = 0.05$, Table A4.1 and Table 7). Comparison with the estimated starting value suggests a slight upward trend in the DS5 price convergence process (from 72.528 to 77.609). This trend is also noticeable in the Fig. 17.

The quantity traded estimated asymptote for the DS5 treatment is 17.111, and this is significantly lower than the competitive norm of 20 ($\alpha = 0.05$, Tables 7 and 4.1). The estimated asymptote in the DS5 market is also significantly different from the asymptotes in both the DS (16.416) and CS (21.316) treatments ($\alpha = 0.05$). There is no obvious upward or downward trend in the convergence of the quantity traded in the DS5 market.

The estimated asymptote for total earnings in the DS5 market is 1095.381, and this is significantly lower than the competitive norm ($\alpha = 0.05$, Tables 7 and 4.1). The DS5 estimated asymptote is also significantly different from the total earnings estimated asymptotes in both the DS (1050.440) and CS (1183.159) treatments ($\alpha = 0.05$). The estimated asymptote for the DS5 total earnings is very close to the estimated starting value suggesting no upward or downward trends in the convergence process.

The buyer earnings estimated asymptote in the DS5 market is 145.272. The asymptote is not significantly different from the competitive norm of 150 and from the estimated asymptote of the CS market ($\alpha = 0.05$, Tables 7 and 4.1). But the DS5 asymptote is significantly lower from the estimated asymptote in the DS market (153.653). A comparison of the asymptote with the estimated starting value suggests a downward trend in the DS5 buyer earnings convergence level.

For seller earnings the estimated asymptote in the DS5 treatment is 129.696 (Table 7). This is significantly lower than both the competitive norm and the estimated asymptote in the CS market (155.282), but significantly higher than the estimated asymptote in the DS market

(108.918) ($\alpha = 0.05$, Tables 7 and 4.1). The seller earnings in the DS5 market converged from below (from 100.434 to 129.696).

Table 7. Estimated Asymptotes and Starting Values for Selected Treatments.

Variable	Centralized Spot (CS)	
	Asymptote	Starting value
Price	81.399 a*	78.708
Quantity Traded	21.316 a	21.922
Total Earning	1183.159 a	1171.344
Buyer Earnings	141.609 a	159.302
Seller Earnings	155.282 a	132.584
Buyer/Seller Earnings Difference	−12.128 a	18.700
Variable	Decentralized Spot with 3 matched pairs (DS)	
	Asymptote	Starting value
Price	74.459 b	73.835
Quantity Traded	16.416 b	16.801
Total Earning	1050.440 b	968.600
Buyer Earnings	153.653 b	152.578
Seller Earnings	108.918 b	88.352
Buyer/Seller Earnings Difference	43.393 b	69.429
Variable	Decentralized Spot with 5 matched pairs (DS5)	
	Asymptote	Starting value
Price	77.609 c	72.528
Quantity Traded	17.111 c	17.288
Total Earning	1095.381 c	1093.108
Buyer Earnings	145.272 a	170.835
Seller Earnings	129.696 c	100.434
Buyer/Seller Earnings Difference	19.641 c	55.733

*a,b,c — same letter indicates no significant difference between estimated asymptotes in the respective equations. A different letter indicates a significant difference between estimated asymptotes, $\alpha = 0.05$.

According to the estimated asymptote, buyer earnings exceed seller earnings by 19.641 in the DS5 market (Table 7). This is significantly different from the competitive norm and also from the estimated asymptotes of buyer/seller earnings difference in both the DS and CS markets (43.393 and −12.128, respectively) ($\alpha = 0.05$, Tables 7 and 4.1). Comparison with the estimated starting value suggests that the buyer/seller earnings difference decreased to the end of the convergence process.

The above analyses suggest that as a result of the increased number of available bargaining matches in a trading cycle of the decentralized spot market both average trade price and quantity traded increased, as compared to those in the decentralized spot market with three available matches in a trading cycle. The increased quantity traded resulted in increased total earnings in the decentralized spot market with five bargaining matches. As a result of the higher average price, the difference between the average buyer and seller earnings decreased, although buyer earnings are still significantly higher than seller earnings. However, both average price and quantity traded in the decentralized spot market with five available bargaining matches in a trading cycle is still significantly lower than in the centralized spot market. As a result, total earnings in the decentralized spot market with five matches is lower than in the centralized market, and the distribution of earnings between buyers and sellers in the former market is still further from the competitive optimum than in the latter market.

5. SUMMARY AND IMPLICATIONS

This study addresses two issues of importance in the evolving market economy of Russia. One, we address the impacts of private negotiation (decentralized) trading versus double auction (centralized) trading in forward and spot deliveries. Two, the impacts of price reports in a decentralized spot market are investigated. The former is important because most trading in the food sector of Russia is via private negotiation, as centralized markets have been slow to develop in this sector. Also, there is little forward delivery, due to uncertainty and an inadequate legal system to enforce contracts. Delivery, therefore, is necessarily spot, *i.e.*, goods are produced in advance of sale.

The bilateral monopoly theoretical model provides a reasonable prediction of behavior in private negotiation trading. Mainly because quantities traded are lower relative to the competitive prediction, private negotiation trading results in reduced total surplus by 16% and 12% in forward and spot deliveries, respectively. Prices are near the competitive level when buyers and sellers have equal bargaining power (forward delivery), however, erode in the case of spot delivery.

We proposed that buyers benefit through increased bargaining power in private negotiation trading with spot delivery, leading to reduced prices and quantities traded. Advance production and a finite number of matches gives buyers monopsony power at the end of a trading cycle that can be carried forward into earlier bargaining sessions. The laboratory results suggest that private negotiation trading and spot delivery can reduce units traded by 25%, trade prices by about 9%, relative to the competitive equilibrium. Privately negotiated spot prices are significantly different than forward prices, and about 7% lower. At the same time, privately negotiated spot prices are not as low as the monopsony solution because of the matching risk buyers face in the latter bargaining sessions when there are three bargaining matches in a trading cycle. Nevertheless, seller earnings in the private negotiation spot market are only 2/3 of buyer earnings, and are 19% lower than in the case of forward delivery. Compared to a spot auction setting, seller earnings are reduced by nearly 30%. Hence, for the same basic supply and demand conditions, seller earnings could rise by more than 40% if trading switched from private negotiation to a double auction. Total surplus in this market would increase by 13%.

Privately negotiated trades carry transactions costs. An auction environment does better in generating surplus for agents primarily because more units are sold. Compared to private negotiation trading, auctions are "matching rich." In a four-and-a-half minute trading period, our private negotiation treatments allowed three matches. In a double auction the four-and-a-half minute trading period allowed continuous matching between buyers and sellers, because the four buyers and four sellers in the market all took part in the negotiation. Effectively, there is more bidding competition in auction trading than in private negotiation trading. Private negotiation can make poor matches in the second and third one-and-a-half minute bargaining rounds. In these rounds a single seller may have moved up the cost schedule and a single buyer may have moved down the redemption schedule sufficiently far enough that there is very little or no motivation for trading. Additionally, in spot delivery incentives can be exhausted in later rounds. In any case, these matches can be poor, and poor matches restrict trading in the overall market. The pairing of agents creates a transaction cost in the market. Valuable negotiating time is wasted that would not be in a double auction.

A related perspective suggests that compared to private negotiation trading, double auction markets are information rich. Buyers and sellers are instantly informed of when trades are made and the trade price. Information is public. Private negotiation restricts such information to the paired buyer and seller making the trade. Learning about the market is confined, and never as extensive as it is in an auction. In transacting with one other agent there is no knowledge of the costs and demands of other traders that may create a "better match," which we define as a trade that generates more surplus between the buyer and seller.

It is often claimed that private negotiation markets can be made more like the information-rich double auction through providing market participants with additional information about the market, especially, with market prices. We argued that providing agents with additional information about market price cannot improve the bargaining position of sellers in decentralized trading and spot delivery, hence, it would not make the private negotiation spot market more competitive. This was supported by the results obtained in our experiments. Alternative types of information in private negotiation trading with spot delivery, as provided in our experiments, do not improve the seller's bargaining position for price and in some cases appear to improve the bargaining position of buyers, relative to that of sellers, putting sellers in a worse position.

Analyses of the laboratory data suggest that sellers adjusted their production decision according to the additionally provided price information, so that the reported price would be a little higher than their marginal production cost. Besides, both sellers and buyers used the information to form their price expectations in the following trading cycles. Buyer market power resulted in reported prices being considered as the upper rather than average price level in the following cycles. When market agents were provided with average price in the decentralized spot market, which tends to the monopsony level, a risk averse seller reduced his/her production relative to the monopsony level price, in order to avoid the situation in which the marginal unit has to be sold at a loss. A buyer, however, maximizing his/her profit responded to the quantity reduction by a further decrease in price (went down the cost schedule). As a result, less quantity was sold and for a lower price.

On the other hand, when prices from the competitive centralized market were reported, a producer responded with increased production and this also resulted in a loss. A buyer does not have an incentive to buy the quantity that exceeds the optimum monopsony level at a price that would cover the production costs because the buyer would not benefit from that decision. Instead, the buyer uses his/her market power and forces the seller to accept a lower price. The seller will do this because he/she would lose all production costs for the extra units, if the lower price offered by the buyer was not accepted. The producer-seller loses again. Seller earnings are significantly lower in each of the information treatments, relative to the no information (DS) treatment. Thus, the additionally provided market price information could hardly make producers better off and, since quantity produced could be decreased, market efficiency would be reduced.

In competitive auction trading in which neither the agents nor the goods being traded have any distinguishing characteristics, the market establishes a clearing price. The clearing price is usually near the predicted competitive equilibrium. Most transactions in this market setting also are completed at or near that price, when agents are given the opportunity to learn. These results change when sellers produce a non-storable product in advance of sale, and buyers and sellers individually negotiate for price during random pairings. Results from our experiments indicate a tendency for sellers to be disadvantaged relative to buyers in their negotiation for price. Moreover, information treatments provided in our experiments do not improve the seller's position, and in some cases make it worse. There is evidence of a "curse of knowledge" for sellers in our information experiments in their negotiation for price, particularly when quantity is implicitly reported (DS/TP), relative to no information.

Centralized trading, as compared to decentralized trading, offers more than an information advantage to agents. It solves the matching problem that exists in private negotiation trading, effectively matching buyers and sellers so that total surplus can be maximized. Price in centralized trading responds to levels of production, whereas in decentralized trading prices tend to be more related to the relative bargaining strengths of buyers and sellers. For example, we noted in our private negotiation experiments that price did not increase, even when production levels declined. However, private negotiation market outcomes move closer to those of the double auction when the number of available bargaining matches increased. The price increase in the market with five trading matches could be attributable to the following: (1) the end-of-period matching risk for a buyer becomes higher when the number of matches increase, (2) sellers have more options and can be more patient in an attempt to find the best match. Evidently, the increased number of available matches brings more competition, through additional options, to the decentralized spot market and this improves the bargaining position of sellers. As a result, buyers bid more and sellers responded with higher production.

These results provide us with implications for advancing the efficiency of markets in Russia and in understanding why market structures have evolved as they have. The key to providing more efficient markets dominated by decentralized trading and spot delivery is to provide means to strengthen the bargaining position of sellers. How might this be done? We have seen that centralized trading improves the competitive environment. The bargaining position of the sellers also is certainly improved when they use forward instead of spot delivery in decentralized trading. In the experiments, market outcomes are also improved as the number of available trading matches increases, even given the same number of agents. This suggests that decentralized trading through computer networks that increases number of potential traders could have a potential in the Russian food market.

Another way to increase the number of available trading matches would be to let intermediaries enter the market. The buyers in our experiments were limited in number. The returns to these few buyers, in fact, acting as intermediaries, are such to entice other intermediaries into the market. Additional intermediaries in the market results in more competition and could provide sellers with more alternatives, although likely increasing their searching and matching costs. Spulber (1999) maintains that as the number of intermediaries increases, prices evolve to the competitive norm. But, intermediaries also add to the costs in the marketing chain. These costs force firms to search for means of coordinating to reduce the costs of transacting. This is likely why we see vertical integration in the Russian food sector, dampening the development of centralized trading. Cooperatives also provide producers in the Russian agricultural sector with the advantage of improving their bargaining position. Each of these implications provides the focus for additional research directed toward improving the efficiency of markets in Russia.

Decentralized markets in a real-world economy are obviously much more complicated than those considered in this study. One important mechanism that may greatly affect market outcomes is reputation. A related mechanism is a trust between trading partners, which also may affect price-quantity patterns; thus, influencing market efficiency. Applying different search mechanisms in private negotiation trading also may influence market outcomes. Each of these additions to the relatively simple experimental market used in our work needs a separate set of experiments to maintain the control that is necessary in economic experiments. Another area for future research is an investigation of the effects of agents' expected prices on their decision processes, when alternative market information scenarios are presented. Such an analysis may show that it is not additional information by itself that is detrimental in improving market efficiency in private negotiation spot trading, but how it is perceived and processed by agents. This study provides the baseline for these possible extensions in future research.

APPENDICES

A1. Economic Models

Two approaches are used to develop the economic models that follow. They are the price theory and game theory approaches. We believe that they complement each other and together give a better understanding of the markets under investigation.

Price Theory Approach. The salient features of the economic setting under investigation are the effects of risks inherent in alternative mechanisms for price discovery. The expected value-variance (EV) approach (Robison and Barry, 1987) is used to model the effects of price risk due to the information differences in centralized and decentralized markets and also risk resulting from spot trading. Risk may be incorporated into an EV model by generally assigning random variables to prices (in our case) and forming the certainty equivalent of the profit expression.

Spot-Centralized Market. The spot market, by definition, occurs after the production decision. Costs become sunk. Thus, there is the possibility for the seller to lose all, or part of, the cost of production, because a unit might not be sold at a price equal to or greater than unit cost. Effectively, this is a risk associated with price in the spot market. Expected price therefore is $E(p + w) = p$, where w is a normally distributed random variable with expected value zero and variance σ_w^2. The distribution of w is assumed to be such that price cannot be negative. Following Robison and Barry (1987), the certainty equivalent of the profit expression for the seller is

$$\pi_{ce} = pq - C(q) - \frac{\lambda_s}{2}(q^2 \ \sigma_w^2), \tag{1}$$

where $C(q)$ is total cost, q is units produced, and λ_s is the Pratt – Arrow measure of risk attitude for the seller. The first order conditions require

$$p = C'(q) + \lambda_s \, q \, \sigma_w^2 \, . \tag{2}$$

As a buyer does not have to incur sunk cost before purchases, the first order conditions in the buyer case require

$$R'(q) = p, \tag{3}$$

where R(q) is total revenue.

The additional cost associated with the price risk from advance production in a spot market should result in reduced quantity for the risk averse seller ($\lambda_s > 0$), as compared to when this risk is not present. Similarly, price is expected to be higher in a spot market than that predicted by the competitive equilibrium model in the absence of price risk due to production before sale (Krogmeier *et al*., 1996). More intuitively, the supply curve in the case of a spot market shifts to the left of that in the competitive equilibrium model.

Spot-Decentralized Market. We have argued previously that price information available to agents in a decentralized market is less than in a centralized market due to the decreased interaction of sellers and buyers. This contributes to the uncertainty in the market. We can model this by assigning a normally distributed random variable (ε) to price (p) in both the cases of the seller and buyer. The expected value of ε is assumed to be zero with variance of σ_ε^2 . Again, we assume the distribution is such that price cannot be negative. In this case, because there is only one buyer and one seller, bilateral monopoly, price also is a function of q. The expected price for the seller in a spot market is $E(p + w + \varepsilon) = p$.

The certainty equivalent of the profit expression for the seller is

$$\pi_{ce} = p(q)q - C(q) - \frac{\lambda_s}{2}(q^2\sigma_w^2 + q^2\sigma_\varepsilon^2 + 2q^2\rho\sigma_w\sigma_\varepsilon), \tag{4}$$

where ρ is the correlation between w and ε. The first order condition for the seller requires

$$p'(q)q + p(q) = C'(q) + \lambda_s(q\sigma_w^2 + q\sigma_\varepsilon^2 + 2\sigma_\varepsilon^2) \tag{5}$$

The certainty equivalent of the buyer's profit expression is

$$\pi_{ce} = R(q) - p(q) - \frac{\lambda_b}{2}(q^2\sigma_\varepsilon^2). \tag{6}$$

The first order conditions for the buyer require

$$R'(q) = p'(q)q + p(q) + \lambda_b(q\sigma_\varepsilon^2) \tag{7}$$

Both buyers and sellers incur risk due to the added cost of information loss in private negotiation relative to centralized auction markets. The seller also has the additional cost of price risk associated with possible inventory loss resulting from production before sale. The quantity traded in this scenario is expected to decline, and total surplus, and thus market efficiency, will be reduced relative to the control case. The impact of private negotiation (decentralized market) on price is uncertain from the model. The negotiated price will depend on the relative risk preferences of the buyer and seller and also on differences in the variances of price risk attributable to both production before sale for the seller and information for both the seller and buyer. Consistent with Buccola (1985), price variance in decentralized markets is expected to be greater than in centralized markets.

The bilateral monopoly theoretical construct provides a starting point to predict behavior of agents in private negotiation. The risk of no exchange and the incentive of buyers and sellers to maximize earnings from trades provide the course of action for strategic behavior. In the absence of information asymmetry and other extraneous forces, such as signaling or communication, bids and offers, and reaction to those bids and offers, provide the information to agents for their strategic behavior. Buyer power and seller power will tend to counteract each other. This does not mean that prices necessarily will end up at the competitive auction equilibrium. Bargaining expertise, relative risk preferences, and strategic behavior impact the final outcome. Moreover, repeated negotiations and random matches of buyer-seller pairs, as in our experiments, also affects behavior. Any buyer advantage will push price closer to seller marginal cost, and seller advantage will push price closer to buyer marginal value. The added risk for sellers due to advance production could be expected to put them at a disadvantage to buyers in the spot decentralized market. This could be expected to push price closer to the seller marginal cost in our spot private negotiation trading.

The economic models developed to this point use price theory as their foundation and offer advantages in that they explicitly consider risks associated with advance production and reduced information available to agents in decentralized trading. Our primary focus has been on market outcomes when individual buyers and sellers are transacting bilaterally, as compared to behavior in centralized trading. This theoretical development, however, does not offer sharp predictions of economic outcomes in the case of private negotiation. We now turn to an alternative theory, namely game theory, which might provide alternative predictions as useful points of reference to which the results of the laboratory experiments can be compared.

Game Theory. Very few game-theory models of the double auction exist, because of the difficulties of modeling strategic behavior on both sides of the market. As a result, there is no generally accepted theoretical model of the double auction (centralized trading). To model the oral double auction, with the bids and offers openly called, is still more difficult because the process takes place over time and agents do not know what prices will be available if they wait instead of trading now (McAfee and McMillan, 1987). Friedman (1984) suggests an approach based on a no-congestion equilibrium concept which uses a hypothetical extra chance game appended to the double auction game. He suggests that if there are three or more traders in a double auction market, and each trader's actions at each time are chosen to maximize expected utility of final holdings (given information currently available to him, his current holdings, and the double auction rules), and the strategy selection results in a no-congestion equilibrium; then the outcome of trading constitutes a price equilibrium. The final holdings are Pareto optimal, and closing market bid and ask prices coincide and support the final holdings. Friedman shows that the outcome is a Walrasian equilibrium.

A private negotiations market could be seen as a sequence of bilateral bargaining. (In the proposed experiment each of the four buyers and each of the four sellers is involved in three, or five in the DS5 treatment, sets of bilateral bargaining with a randomly matched partner. No resale is permitted.) Bilateral bargaining, perhaps, is the most primitive and widely used trading institution. Despite its simplicity, unstructured bilateral bargaining is difficult to analyze, because it occurs in a free-form context, with no restriction on which party makes the first or any subsequent offer. Either party can terminate the bargaining by accepting the current proposal of the offer (Davis and Holt, 1993).

To characterize an equilibrium under bilateral bargaining we follow the approach offered by Gibbons (1992). As the dynamics of the unstructured bargaining seems impossible to formalize, we will consider a static Bayesian game. Let the valuation for a unit be v (value) for the buyer and c (cost) for the seller. These valuations are private information and are drawn from independent distributions V and C, respectively. If the buyer gets the unit for price p, then the buyer's utility[9] is $(v - p)$; if there is no trade, then the buyer's utility is zero. If the seller sells the good for price p, then the seller's utility is $(p - c)$; if there is no trade, then the seller's utility is $(-c)$ due to the advance production. We analyze the following trading game: the seller chooses the lowest price p_s he is willing to accept for the unit, and the buyer simultaneously chooses the highest p_b he is willing to pay for the unit. (Hence, we omit the dynamics of the negotiation by introducing these reservation prices.) A trade occurs if $p_b \geq p_s$ and we assume that the transaction price will be $p = (p_b + p_s)/2$,

[9] This is the change in the buyer's total utility.

i.e., as a result of negotiations the parties split the difference ($p_b - p_s$) equally. In the case of no trade the parties start new games with other random partners.

In this game G, a strategy for the buyer is a function $p_b(v;\, p_b^1, \dots, p_b^{G-1})$ specifying the reservation price the buyer will choose depending on the value and the prices paid in previous games. Likewise, a strategy for the seller is a function $p_s(c;\, p_s^1, \dots, p_s^{G-1})$ specifying the reservation price the seller will choose depending on the cost and the prices received in previous games. A pair of strategies (p_b, p_s) is a Bayesian Nash equilibrium if the following two conditions hold. For each $v \in V$, $p_b(v;\, p_b^1, \dots, p_b^{G-1})$ solves

$$\max_{p_b}\left[v - \frac{p_b + E\left[p_s(c; p_s^1, \dots, p_s^{G-1}) \middle| p_b \geq p_s(c; p_s^1, \dots, p_s^{G-1})\right]}{2}\right] \times$$

$$\times \operatorname{Prob}\left\{p_b \geq p_s(c,\, p_s^1, \dots, p_s^{G\text{-}1})\right\} \ , \quad (8)$$

where $E[\underline{p_s}(c;\ p_s^1, \dots, p_s^{G-1}) \,|\, p_b \geq p_s(c;\ p_s^1, \dots, p_s^{G-1})]$ is the seller's expected reservation price, conditional on the seller's reservation price being less than the buyer's reservation price.

For each $c \in C$, $p_s(c;\ p_s^1, \dots, p_s^{G-1})$ solves

$$\max_{p_s}\left[\frac{p_s + E\left[p_b(v; p_b^1, \dots, p_b^{G-1}) \middle| p_b(v; p_b^1, \dots, p_b^{G-1}) \geq p_s\right]}{2} - c\right] \times$$

$$\times \operatorname{Prob}\left\{p_b(v; p_b^1, \dots, p_b^{G\text{-}1}) \geq p_s\right\} \ , (9)$$

where $E[p_b(v;\ p_b^1, \dots, p_b^{G-1}) \,|\, p_b(v;\ p_b^1, \dots, p_b^{G-1}) \geq p_s]$ is the buyer's expected reservation price, conditional on the buyer's reservation price being greater than the seller's reservation price.

There are many Bayesian Nash equilibria of this game. The number of equilibria also is increased by the presence of the sunk production cost in spot delivery, because a seller may have to accept a price less than his cost, which would never be the case in a forward market situation. The availability of the outside options represented with prices the parties agreed upon in other games, however, narrows the range of possible equilibria as compared with the case of "pure" bilateral bargaining. In the case of the transparent market (where information from previous trades in the market is made available prior to bilaterally negotiating for price), the range of possible equilibria may be narrowed even more as strategies of both buyer and seller would be dependent on the reported market price: $p_b(v;\ p_b^1,\ \ldots,\ p_b^{G-1};\ p_m)$ and $p_s(c;\ p_s^1,\ \ldots,\ p_s^{G-1};\ p_m)$, respectively, where p_m is the reported market price.

The suggested model still cannot determine the exact market outcomes in the case of the private negotiations as compared with the centralized market; both designed as spot trading. However, it can be argued that the buyer is in a stronger bargaining position than the seller in a dyadic negotiation of prices in spot trading.[10] A buyer may understand that the seller has the risk of losing the cost of production if units are not sold.[11] This puts the seller at a decisive disadvantage to the buyer in the negotiation process and forces the seller to accept lower bids from the buyer, even for the reduced quantities produced. Buyers may not be willing to bid prices up to receive a greater quantity if they can achieve gains from lower prices on fewer units to offset unrealized gains from trading more units. We might, therefore, expect prices in decentralized spot markets to be less than those in centralized spot markets. Total surpluses also are expected to be less. The more competitive nature of centralized spot markets, *i.e.*, the interaction of many buyers and sellers, tends to mitigate the stronger bargaining position the buyer has in decentralized spot markets.

A2. An Example of the Experiment Instructions — Private Negotiation (Decentralized) Spot Market

Introduction. This is an experiment in the economics of market decision making. In this experiment, we will set up a market in which some of you

[10] If we model the profit objective of an advance production (spot) seller, it must hold that the quantity in stock (q_m) is greater than or equal to the amount sold (q_s). So the seller faces a constraint in a Lagrangian objective that we write as $\lambda(q_m - q_s) \geq 0$, where the multiplier λ in the first order condition is the marginal inventory cost; it effectively shifts a comparable forward or production-to-demand supply curve to the left. Thus, spot costs are never lower than costs in the production-to-demand institution. The impact of the inventory cost on trading prices is an empirical question. Over time, however, we would expect sellers to learn about the equilibrium quantity and prices in a spot market to adjust production accordingly. Left over stock should decline, and we therefore expect λ to decline.

[11] If a buyer fails to purchase a unit, he earns zero; if a seller fails to sell a produced unit, he loses the cost of production.

will be BUYERS and some of you will be SELLERS. You have been provided with either BUYER RECORD SHEETS or SELLER RECORD SHEETS. The sheets you have received designate whether you are a buyer or a seller in this experiment. These record sheets will be used for the purpose of illustration only. You will receive actual record sheets just prior to the beginning of the actual experiment.

The commodity you are trading is referred to as a "unit". Sellers make earnings by producing units at a cost and selling these units to buyers. Buyers make earnings by purchasing units from sellers and then redeeming (or reselling) these units to the experimenter. Earnings are recorded in a fictitious currency called tokens. Tokens are exchanged for cash at the rate of **35 tokens = 1 rubles**. Your earnings will be paid to you in CASH at the end of the experiment. To begin, every seller and buyer will be given an initial balance of **700 tokens (20 rubles)**. You may keep this money PLUS any you earn.

Buyers and sellers will be randomly paired and will exchange units for tokens in a computerized market or auction over a sequence of trading periods. Each trading period consists of three trading sessions during which pairs of buyers and sellers negotiate trading prices. The organization of a trading period is depicted below in Fig. 3. Each trading period consists of a production decision and trading sessions. During the production period, sellers decide on the number of units to produce for the trading period. Any units produced are then available to sell in the three trading sessions. Meanwhile, during the production decision buyers are

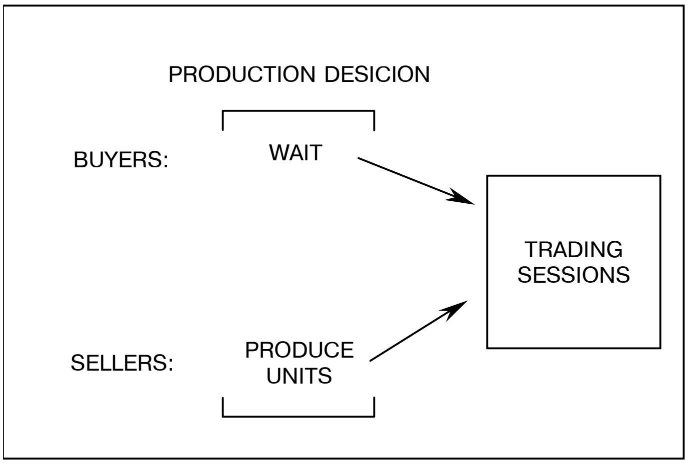

Fig. 3. Organization of Trading Period.

waiting for the trading to begin. Trading, therefore, occurs after sellers have produced units. Sellers have units ready (or "in stock") to be sold. We have provided example computer screens for buyers and sellers during this phase of the trading period. Unit values are exhibited for the buyers and sellers to see their unit costs. (Unit values and unit costs are discussed later.) The seller makes the production decision by clicking on the arrows in the upper left corner of their respective screens using the computer mouse. The production decision amount is then displayed in the "Number Produced" box on the screen. Sellers also see unit costs and total costs of units produced. Both buyers and sellers simply click on "OK" when they are ready to move to the next phase of the experiment.

Specific Instructions to Buyers. If you have been designated as a buyer, please refer to your BUYER RECORD SHEET for practice period 1. Remember, the values on this sheet are hypothetical. You will receive actual record sheets (with values for the experiment) after the practice trading period.

During each trading period you are free to purchase up to 8 units in the trading. For the first unit that you buy, you will receive the amount listed under VALUE for Unit 1. In this example, this amount is 529 tokens. Unit 1's redemption value is 529 tokens. For the second unit that you buy you will receive the amount listed under VALUE for Unit 2, which is 483 tokens. The redemption values for subsequent units are found in the same way.

The earnings or profits from each unit that you purchase (which are yours to keep) are computed by taking the difference between the value and purchase price of the unit bought. That is,

Profit = Value − Price

Suppose, for example, that you buy 3 units in a trading period. If you pay 80 tokens for the first unit, 300 tokens for the second unit, and 300 tokens for the third, your earnings are:

Profit for Unit 1 = 529 − 80 = 449

Profit for Unit 2 = 483 − 300 = 183

Profit for Unit 3 = 431 − 300 = 131

Period Earnings = 449 + 183 + 131 = 763 tokens

There are blanks on the record sheet for recording the purchase price and earnings of each unit that you may purchase. The purchase prices and earnings, from the above example, have been recorded in the appropriate spaces. During the experiment you may record this information as you purchase units OR you may wait until the end of the trading period when this information will be summarized on your computer screen. We recommend the latter as trading occurs rapidly. Buyers also should be aware that they will not be allowed to spend more tokens buying units than what they have in their beginning balance in any one period.

Specific Instructions to Sellers. If you have been designated as a seller, please refer to your SELLER RECORD SHEET for practice period 1. Remember, the costs on this sheet are hypothetical. You will receive actual record sheets (with costs for the experiment) after the practice cycle.

During each trading period you are free to produce and sell up to 8 units. The first unit that you produce during a trading period will cost you the amount listed under COST for Unit 1. In this example, this cost is 71 tokens. Unit 1's cost is 71 tokens. The second unit that you produce will cost you the amount listed under COST for Unit 2, which is 117 tokens. The unit costs for subsequent units are found in the same way.

The earnings or profits from each unit that you produce and sell (which are yours to keep) are computed by taking the difference between the sale price and unit cost of the unit sold. That is,

Profit = Price − Cost

Suppose, for example, that you produce 3 units. You would then have Unit 1, Unit 2, and Unit 3 to sell in the spot market. Be aware that if you sold only 2 units in the auction, in other words you failed to sell Unit 3, you would still incur the cost of producing Unit 3. If this were the case, your unit earnings for Unit 3 would be —169 tokens (*i.e.*, your unit earnings for Unit 3 would be negative).

Let's, however, suppose that you do sell all 3 units at the following prices: Unit 1 for 80 tokens, Unit 2 for 300 tokens, and Unit 3 for 300 tokens. Your earnings would then be:

Profit for Unit 1 = 80 − 71 = 9

Profit for Unit 2 = 300 − 117 = 183

Profit for Unit 3 = 300 − 169 = 131

Total Earnings = 9 + 183 + 131 = 323 tokens

There are blanks on the record sheet for recording the sale price and unit earnings of each unit that you may produce and sell. The sale prices and earnings from the above example have been recorded in the appropriate spaces. During the experiment you may record this information as you sell units OR you may wait until the end of the period when this trading information will be summarized on your computer screen. Again, we recommend the latter. Sellers also should be aware that they will not be allowed to incur a production cost greater than the amount in their beginning token balance in any one trading period.

Trading Rules. Only one unit may be bought and sold at a time. A buyer makes bids to the seller to purchase a unit. A "bid" is a proposed price at which a buyer is willing to purchase a unit. Bids must become progressively higher. In other words, if the first bid for a unit is 100 tokens, then the second bid must be higher than 100. Suppose the second bid is 120 tokens, then the third bid must be higher than 120, and so on. The highest bid existing at any one time will be displayed on the computer screen as the BID.

A seller makes offers to sell a unit. An "offer" is a proposed price at which a seller is willing to sell a unit. Offers must become progressively lower. In other words, if the first offer to sell a unit is for 200 tokens, then the second offer must be lower than 200. Suppose the second offer is 180 tokens, then the third offer must be less than 180, and so on. The lowest offer existing at any one time will be displayed on the computer screen as the OFFER.

There is one further set of restrictions on bids and offers. The reason for these restrictions is just common sense. A buyer's bid cannot be higher than the seller's OFFER. In other words, a buyer cannot attempt to pay a price which is higher than that which the seller is willing to sell for. Similarly, a seller's offer cannot be lower than the buyer's BID. In other words, a seller cannot attempt to sell at a price below that which the buyer is willing to pay.

A bid is made by typing the bid in the space labeled "Bid" on the computer screen, and pressing the ENTER key. Similarly, an offer is made by typing the offer in the space labeled "Offer" on the computer screen, and pressing the ENTER key. During an auction, a buyer will be making bids at the same time that a seller is making offers.

It should be apparent that the difference between the BID and the OFFER gradually decreases. A trade is made when the BID equals the OFFER. Suppose the BID is 150 tokens and the OFFER is 160 tokens. If a buyer decided that he or she was willing to purchase the unit for 160 tokens, he or she could type the number 160 and then press ENTER. There is, however, a quicker method to do this. As soon as the buyer saw the OFFER was 160, he or she could simply clicking on the "Accept Offer" box displayed at the bottom of the computer screen. Whenever a buyer clicks on "Accept Offer", he or she automatically makes a bid which equals the OFFER or, in other words, "accepts" the OFFER.

As another example for sellers, suppose again that the BID is 150 and the OFFER is 160. If a seller decided that he or she was willing to sell the unit for 150 tokens, he or she could type the number 150 and then press ENTER. Again, there is a quicker method to do this. As soon as the seller saw the BID was 150, he or she could click on the "Accept Bid" displayed on the computer screen. Whenever a seller clicks on "Accept Bid", he or she automatically makes an offer which equals the BID or, in other words, "accepts" the BID.

After a seller and buyer have made a trade, the trade price will be displayed and each move to the next unit, which will be highlighted in yellow. After a trade has been made, BID and OFFER values are cleared from the screen. A buyer and seller pair may then resume entering bids and offers for additional units. Trades are made between buyers and seller pairs for one minute and one-half. After a minute and one-half has elapsed, buyers and sellers are again randomly paired.

Each trading period has a maximum time limit of 4.5 minutes or three one minute trading sessions. The time remaining in the session is provided in the "Clock" displayed in the top right corner of the screen. An auction may be terminated sooner than this by a vote to stop trading by either the buyer or the seller. In order to vote to stop trading, click on "Vote to Stop".

At the end of every trading period, which includes three trading sessions, the computer will automatically account for sales or purchases that you have made and adjust your token balance accordingly. A listing of sales or purchases you have made and your adjusted token total balance will be displayed on your computer screen at the end of every period. After you have viewed and recorded this information and click on "OK", a new trading period with three trading sessions will begin. This experiment will consist of approximately 15 to 20 trading periods. The trading period and session numbers are provided in the top left corner of the computer screen. We will conduct a practice run to familiarize you with the mechanics of the computerized market before the actual experiment begins.

Your Name and Identification Number. Before seeing the described windows, the computer will ask for your name and identification number. The bids and earnings of people in the experiment are confidential. Please do not look at someone else's screen and do not speak to another participant once the experiment begins. You may ask the experimenter questions at any time during the experiment. Are there any questions before we conduct the practice session?

A3. Market Outcomes by Period for Selected Treatments

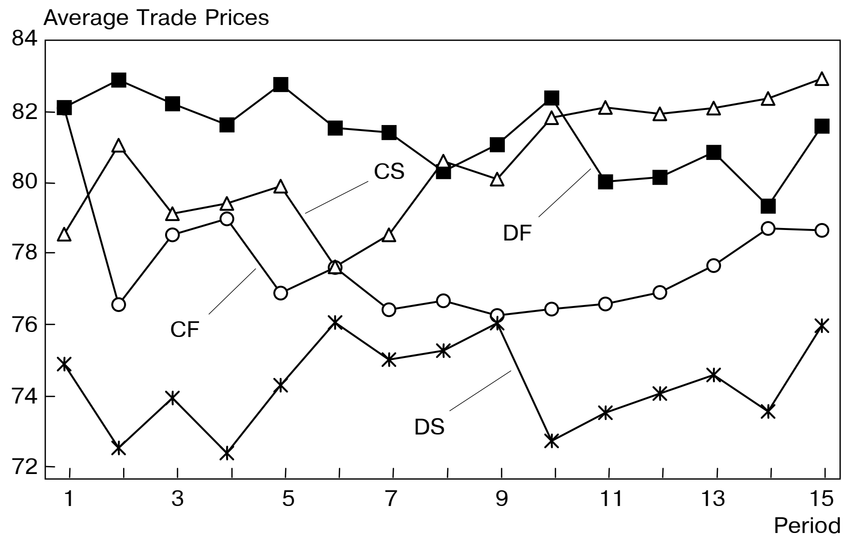

Fig. 4. Average Trade Prices in Centralized and Decentralized Forward and Spot Markets.

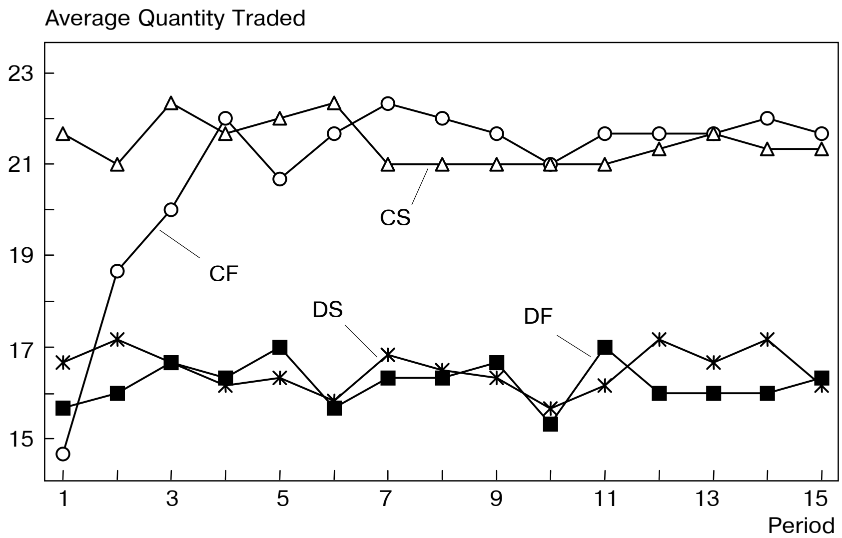

Fig. 5. Average Quantity Traded in Centralized and Decentralized Forward and Spot Markets.

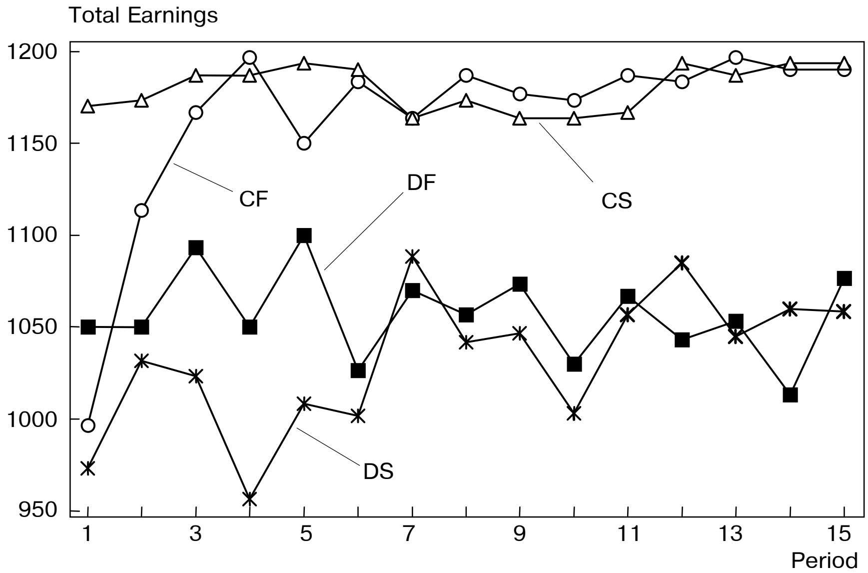

Fig. 6. Total Earnings in Centralized and Decentralized Forward and Spot Markets.

Fig. 7. Average Seller Earnings in Centralized and Decentralized Forward and Spot Markets.

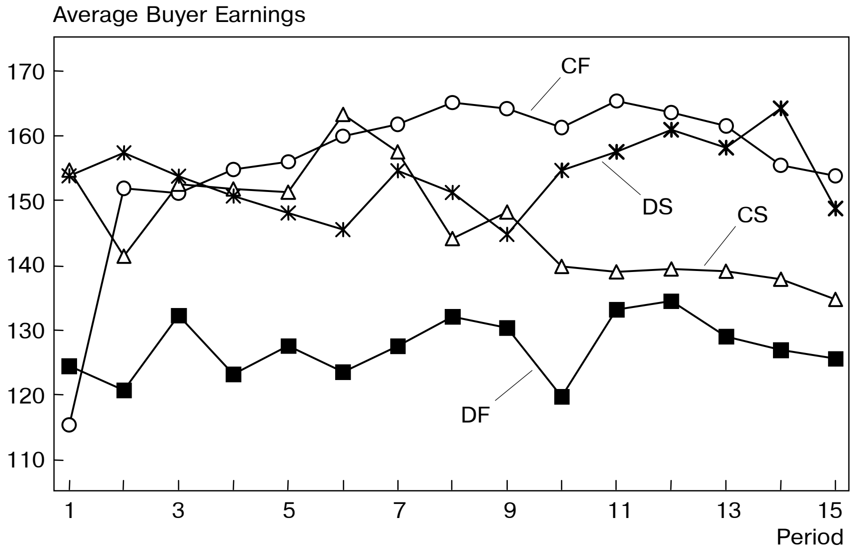

Fig. 8. Average Buyer Earnings in Centralized and Decentralized Forward and Spot Markets.

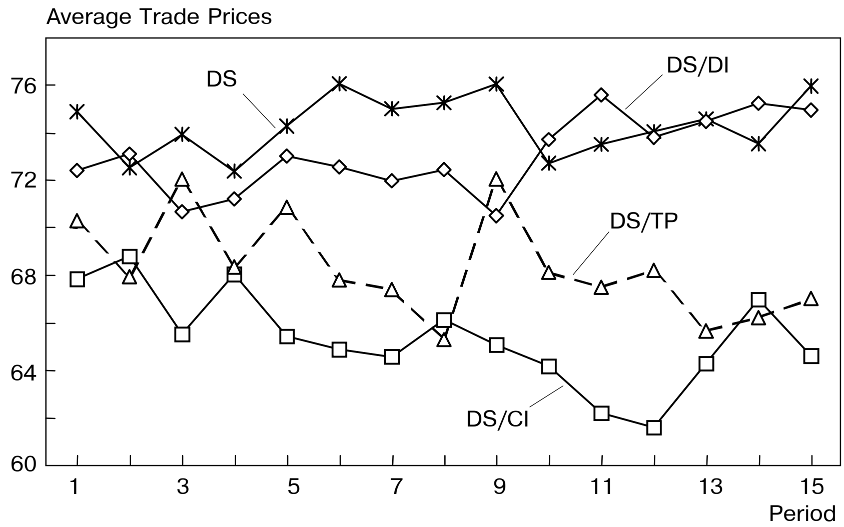

Fig. 9. Average Trade Prices in Decentralized Spot Markets with and without Market News Service.

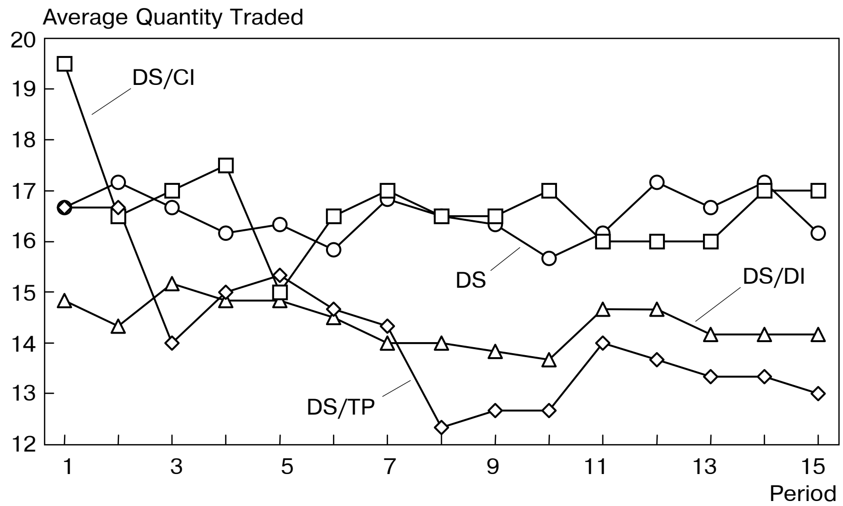

Fig. 10. Average Quantity Traded in Decentralized Spot Markets with and without Market News Service.

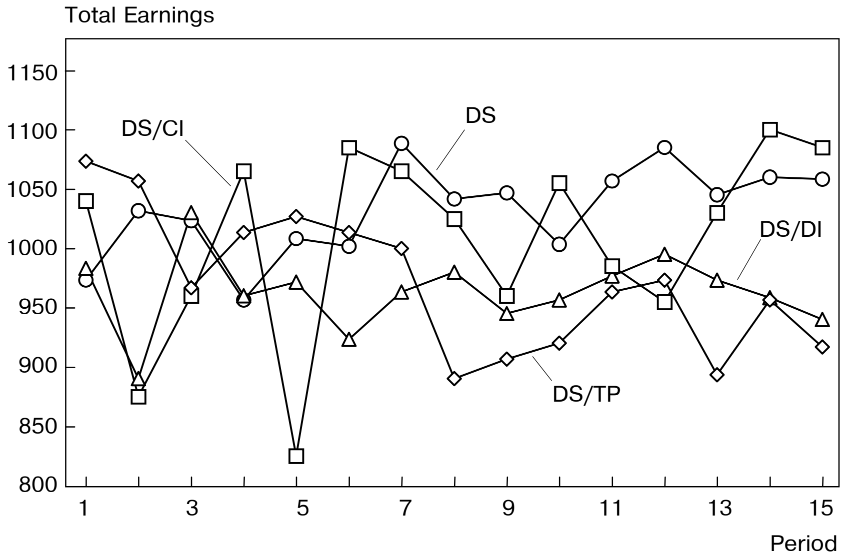

Fig. 11. Total Earnings in Decentralized Markets with and without Market News Service.

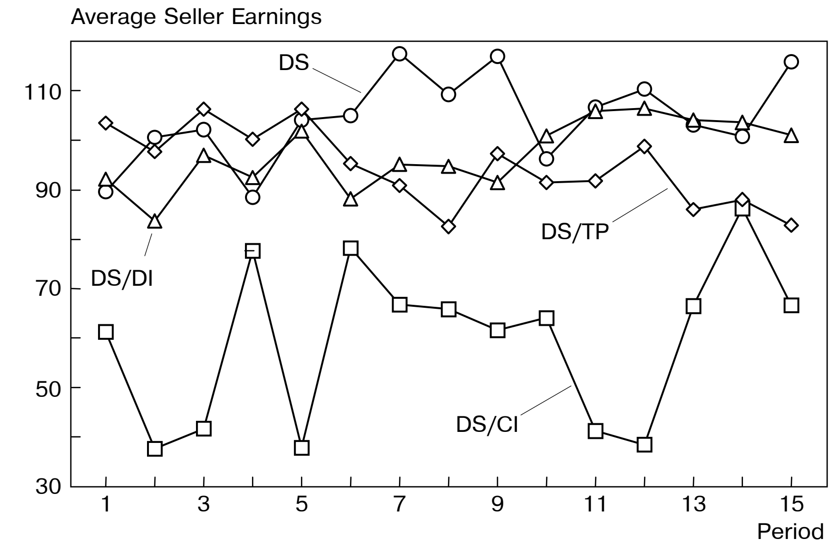

Fig. 12. Average Seller Earnings in Decentralized Spot Markets with and without Market News Service.

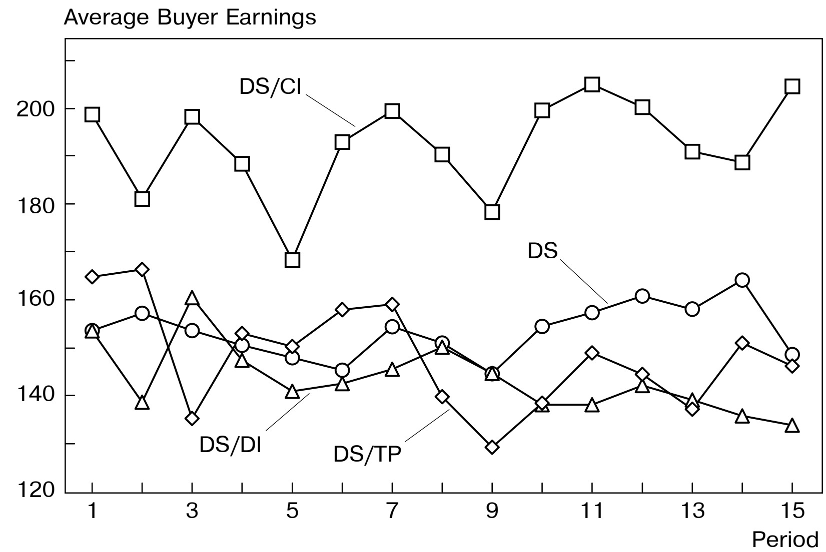

Fig. 13. Average Buyer Earnings in Decentralized Markets with and without Market News Service.

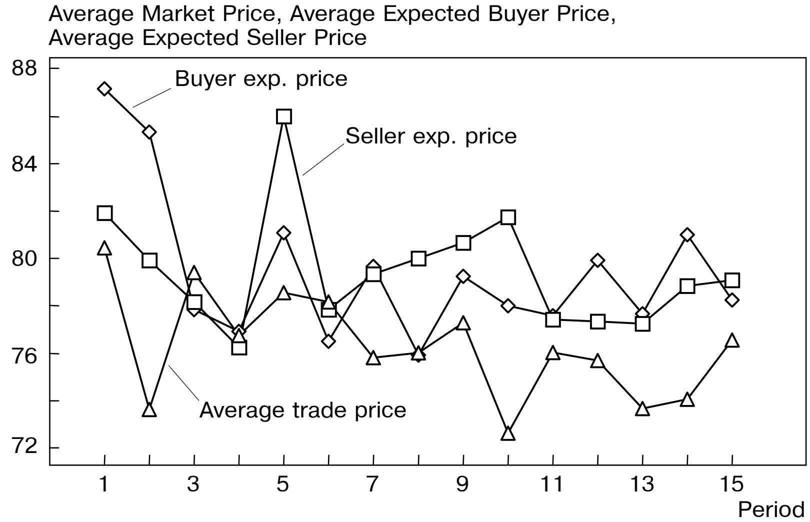

Fig. 14. Average Market Price, Average Expected Buyer Price, and Average Expected Seller Price in the Three Replications of the Decentralized Spot Market (DS).

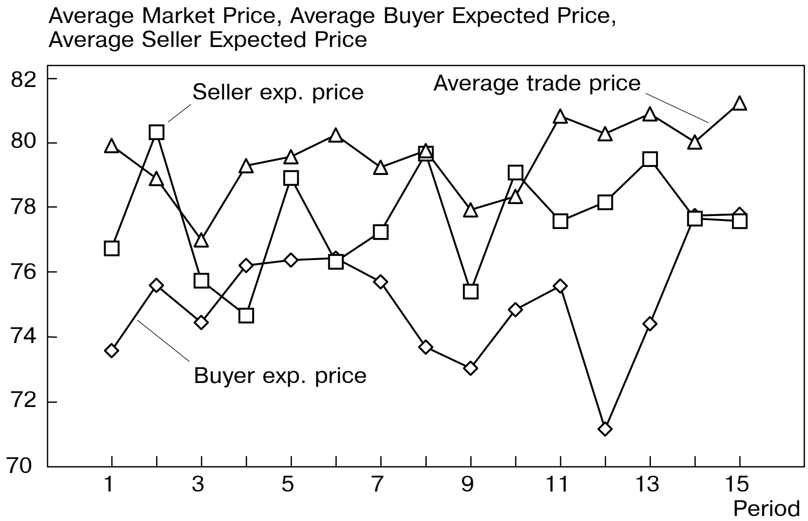

Fig. 15. Average Market Price, Average Buyer Expected Price, and Average Seller Expected Price in the Three Replications of the Decentralized Spot Market with Decentralised Average Price Reports (DS/DI).

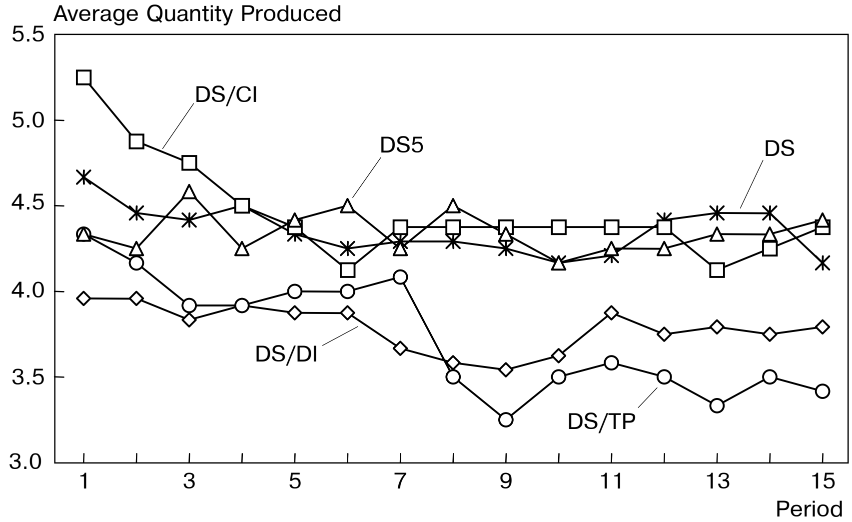

Fig. 16. Average Quantity Produced by a Seller in Decentralized Spot Markets.

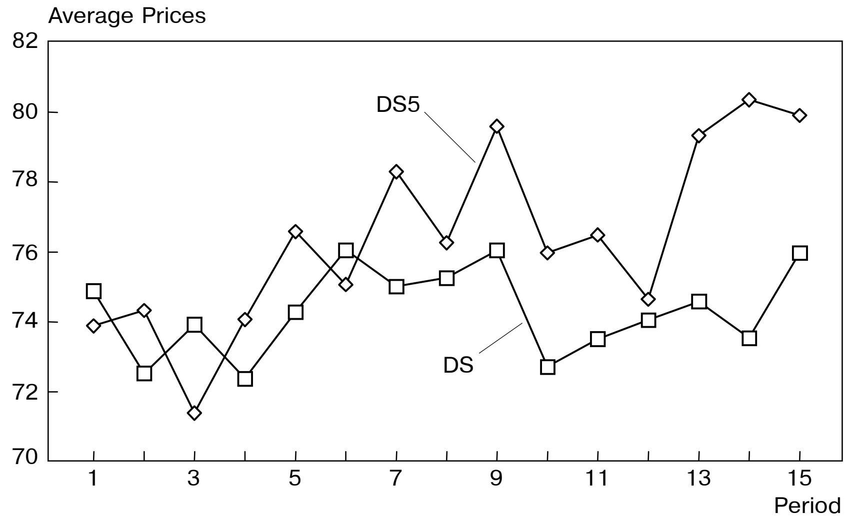

Fig. 17. Average Prices in Decentralized Spot Markets with 3 Matched Pairs (DS) and 5 Matched Pairs (DS5).

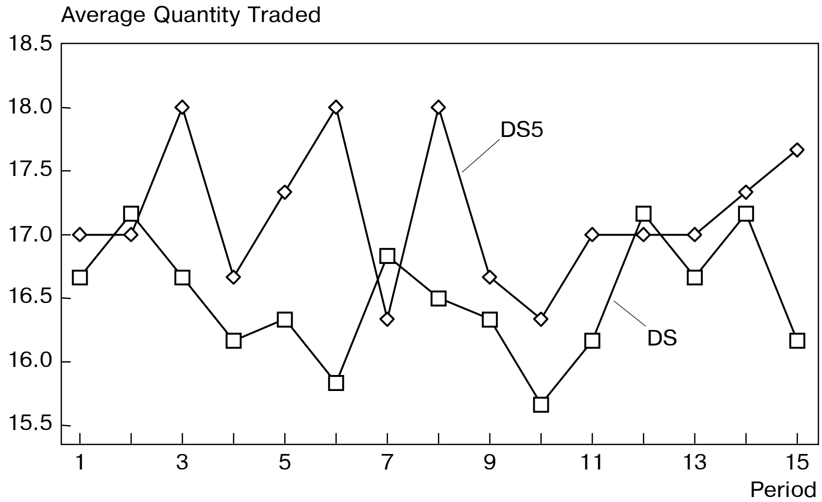

Fig. 18. Average Quantity Traded in Decentralized Spot Markets with 3 Matched Pairs (DS) and 5 Matched Pairs (DS5).

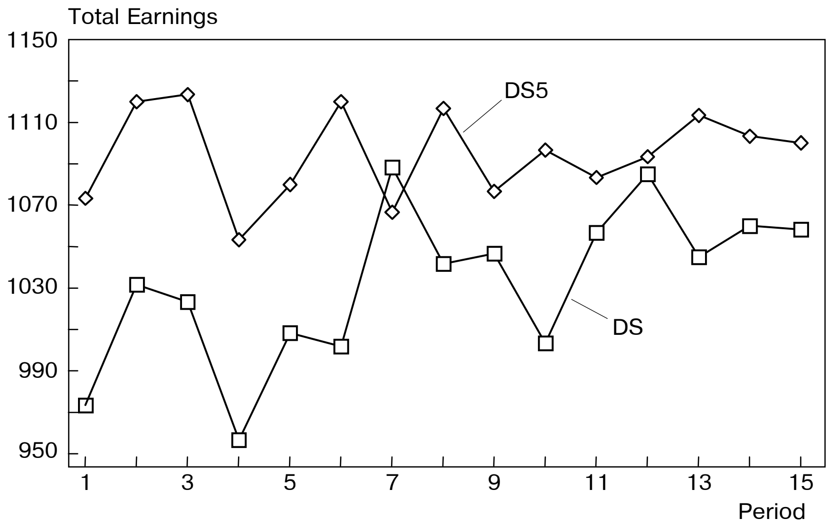

Fig. 19. Total Earnings in Decentralized Markets with 3 Matched Pairs (DS) and 5 Matched Pairs (DS5).

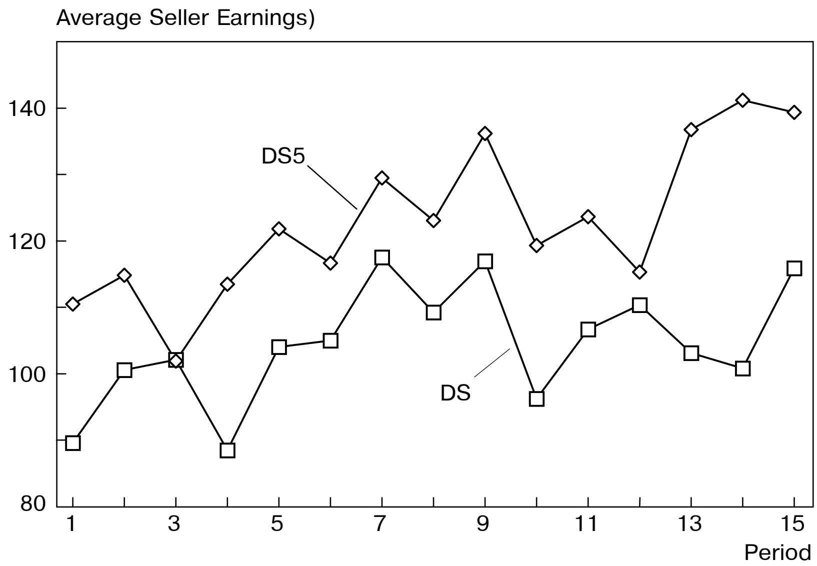

Fig. 20. Average Seller Earnings in Decentralized Markets with 3 Matched Pairs (DS) and 5 Matched Pairs (DS5).

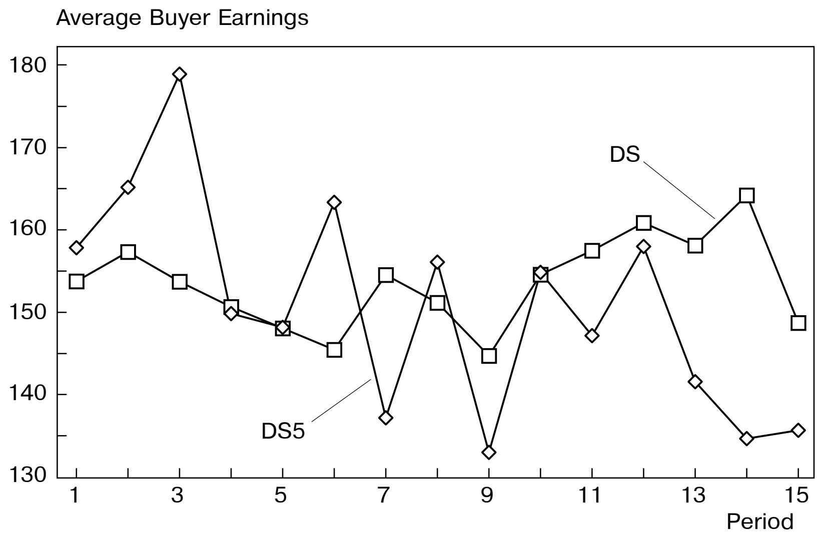

Fig. 21. Average Buyer Earnings in Decentralized Markets with 3 Matched Pairs (DS) and 5 Matched Pairs (DS5).

A4. Statistical Test Results

Table A4.1. Estimated Coefficients (Standard Errors) — Convergence Models for Price, Quantities Traded, Total Earnings, Buyer Earnings, Seller Earning, and Buyer/Seller Earnings Difference.

Variable	Forward Centralized		Forward Decentralized		Spot Centralized	
	As Compared with Competitive Norm					
	Asymptote	Starting point	Asymptote	Starting point	Asymptote	Starting point
Price (CN** = 80) R^2 = 0.9999	−3.321* (0.410)	1.218 (0.983)	0.920* (0.303)	2.833* (0.764)	1.399 (0.871)	−1.292 (1.138)
Quantity Traded (CN = 20) R^2 = 0.9999	2.605* (0.195)	−5.176* (0.466)	−3.670* (0.096)	−4.158* (0.249)	1.316* (0.184)	1.922* (0.385)
Total Earning (CN = 1200) R^2 = 0.9999	7.265 (5.295)	−191.209* (12.646)	−144.743* (4.818)	−138.77* (13.441)	−16.841* (6.225)	−28.656* (9.479)
Buyer Earnings (CN = 150) R^2 = 0.9999	16.320* (1.975)	−31.407* (4.214)	−21.122* (1.121)	−28.39* (3.034)	−8.391 (4.479)	9.302 (6.777)
Seller Earnings (CN = 150) R^2 = 0.9999	−13.998* (.381)	−18.447* (5.061)	−14.955* (1.660)	−6.916 (4.400)	5.282 (5.087)	−17.416* (7.345)
Buyer/Seller Earnings Difference (CN = 0) R^2 = 0.9831	31.533* (4.298)	−18.625* 8.893)	−6.137* (2.696)	−21.894* (6.744)	−12.128 (9.504)	18.700 (14.044)

Variable	Spot Decentralized		Spot Decentralized/ Decentralized Price Reports		Spot Decentralized/ Centralized Price Reports	
	As Compared with Competitive Norm					
	Asymptote	Starting point	Asymptote	Starting point	Asymptote	Starting point
Price (CN** = 80) R^2 = 0.9999	−5.541* (0.405)	−6.165* (0.987)	−6.585* (0.709)	−7.733* (1.179)	−15.720* (0.603)	−10.936* (1.430)
Quantity Traded (CN = 20) R^2 = 0.9999	−3.584* (0.161)	−3.199* (0.397)	−5.778* (0.174)	−5.029* (0.320)	−3.879* (0.191)	−1.177* (0.492)
Total Earning (CN = 1200) R^2 = 0.9999	−149.56* (11.592)	−231.4* (27.768)	−232.511* (6.502)	−253.785* (16.749)	−175.181* (21.011)	−267.734* (55.762)

Continued from p. 65

Variable	Spot Decentralized		Spot Decentralized/ Decentralized Price Reports		Spot Decentralized/ Centralized Price Reports	
	As Compared with Competitive Norm					
	Asymptote	Starting point	Asymptote	Starting point	Asymptote	Starting point
Buyer Earnings (CN = 150) $R^2 = 0.9999$	3.653 (2.387)	2.578 (5.110)	−9.894* (2.078)	5.408 (4.921)	42.593* (3.354)	41.441* (8.565)
Seller Earnings (CN = 150) $R^2 = 0.9999$	−41.082* (2.229)	−61.648* (5.706)	−49.730* (2.085)	−62.642* (4.962)	−86.787* (4.783)	−104.139* (11.831)
Buyer/Seller Earnings Difference (CN = 0) $R^2 = 0.9831$	43.393* (3.415)	69.429* (8.267)	41.927* (4.270)	57.930* (6.700)	131.520* (6.879)	138.019* (16.241)

Variable	Spot Decentralized/All Trade Prices Reported		Spot Decentralized/ 5 Matched Pairs	
	As Compared with Competitive Norm			
	Asymptote	Starting point	Asymptote	Starting point
Price (CN** = 80) $R^2 = 0.9999$	−12.270* (0.524)	−9.628* (1.299)	−2.391* (0.881)	−7.472* (1.989)
Quantity Traded (CN = 20) $R^2 = 0.9999$	−6.817* (0.319)	−2.639* (0.740)	−2.889* (0.129)	−2.712* (0.336)
Total Earning (CN = 1200) $R^2 = 0.9999$	−268.953* (15.715)	−85.957* (34.269)	−104.619* (5.317)	−106.892* (13.933)
Buyer Earnings (CN = 150) $R^2 = 0.9999$	−7.160* (3.013)	17.513* (7.568)	−4.728 (3.217)	20.835* (8.469)
Seller Earnings (CN = 150) $R^2 = 0.9999$	−60.168* (2.565)	−39.706* (5.729)	−20.304* (3.983)	−49.566* (8.627)
Buyer/Seller Earnings Difference (CN = 0) $R^2 = 0.9831$	52.210* (3.886)	59.097* (9.764)	19.641* (7.009)	55.733* (16.782)

* — significantly different from 0, $\alpha = 0.05$;

** — Competitive Norm.

Table A4.2. Estimated Coefficients (Standard Errors) — Models for Trade Price, Seller Expected Price, and Buyer Expected Price.

Variable	Trade Price ($R^2 = 0.9433$)	Seller Expected Price ($R^2 = 0.5312$)	Buyer Expected Price ($R^2 = 0.5084$)
Intercept	62.71167* (10.6395)	67.88941* (9.3803)	58.09726* (10.9247)
EPS**	0.26214* (0.0805)		
EPB	−0.125* (0.0540)		
TPLAG	0.031917 (0.1134)	0.150269 (0.1222)	0.278934 (0.1424)
MPDUM	−40.101* (10.6528)	−26.227* (10.1931)	−40.8736* (13.2711)
MPEPS	−0.49528* (0.1031)		
MPEPB	−0.02963 (0.0796)		
MPTPLAG	1.057827* (0.1227)	0.306666* (0.1339)	0.426021* (0.1701)

* significantly different from 0, $\alpha = 0.05$;
** EPS — Seller's Expected Price (average per period in a replication);
EPB — Buyer's Expected Price (average per period in a replication);
TPLAG — Previous Period Trade Price (average per period in a replication);
MPDUM — dummy for the DS/DI treatment;
MPEPS = EPS*MPDUM;
MPEPB = EPB*MPDUM;
MPTPLAG = TPLAG*MPDUM.

A5. Pattern of Trades

Table A5.1. Percent Trades and Average Trade Prices for Each Bargaining Session by Treatment Across Replications and Trading Cycles 11 – 15.

Treatment	Percent Trades				
	Session 1	Session 2	Session 3	Session 4	Session 5
DF	41.80	34.00	24.20		
DS	38.35	32.66	28.99		
DS/DI	41.75	27.26	30.99		
DS/CI	48.50	23.60	27.90		
DS/TP	43.23	25.05	31.72		
DS5	38.08	22.96	20.26	7.68	11.02
Treatment	Average Trade Price				
	Session 1	Session 2	Session 3	Session 4	Session 5
DF	82.38	79.80	79.15		
DS	76.78	74.75	70.42		
DS/DI	76.34	77.07	70.84		
DS/CI	61.54	67.53	65.18		
DS/TP	69.55	67.65	63.77		
DS5	78.19	80.76	80.95	77.61	66.48

A6. Price Variance

Table 6.1. Price Variance by Treatments and Replications.

Treatment and replication	Period				
	1	2	3	4	5
DS					
1st rep.	194.94	218.40	157.09	139.75	245.57
2nd rep.	183.52	146.27	194.31	89.05	164.82
3d rep.	442.97	195.20	260.33	140.10	236.45
4th rep.	164.97	169.36	71.04	44.51	90.15
5th rep.	124.37	230.15	86.12	102.03	85.53
6th rep.	386.99	145.46	223.85	147.21	483.97

Continued from p. 68

Treatment and replication	Period				
	1	2	3	4	5
DS/DI					
1st rep.	113.65	130.33	103.00	228.63	160.45
2nd rep.	112.91	129.83	101.30	73.50	65.30
3d rep.	445.69	683.26	668.20	591.07	603.56
4th rep.	110.88	110.93	136.93	298.28	153.13
5th rep.	143.65	219.56	166.64	284.99	468.10
6th rep.	143.36	150.06	170.02	149.16	52.81
DS/CI					
1st rep.	206.06	171.51	242.25	123.72	97.11
2nd rep.	178.58	312.30	329.33	283.85	309.21
DS/TP					
1st rep.	164.42	88.42	62.85	24.82	131.54
2nd rep.	109.29	110.02	298.30	131.06	148.45
3d rep.	70.70	128.78	66.02	214.97	244.40
Treatment and replication	Period				
	6	7	8	9	10
DS					
1st rep.	246.88	185.04	167.32	166.77	201.36
2nd rep.	141.84	141.33	78.77	93.73	58.57
3d rep.	197.30	269.65	127.28	65.52	154.24
4th rep.	187.13	77.76	88.60	142.06	32.69
5th rep.	95.26	127.78	123.60	64.29	92.97
6th rep.	86.73	217.52	302.71	173.94	206.86
DS/DI					
1st rep.	139.72	189.34	131.42	180.71	147.15
2nd rep.	72.31	109.65	29.76	157.98	20.72
3d rep.	829.60	691.96	625.63	276.29	882.06
4th rep.	285.58	131.21	158.03	195.31	195.94
5th rep.	205.74	189.86	141.40	405.26	592.57
6th rep.	218.50	267.19	258.08	114.17	272.42
DS/CI					
1st rep.	162.78	183.53	106.02	207.13	77.93
2nd rep.	194.12	212.25	234.70	210.53	114.60

Continued from p. 69

Treatment and replication	Period				
	6	7	8	9	10
DS/TP					
1st rep.	66.45	78.75	66.28	180.68	61.75
2nd rep.	112.98	82.38	94.73	141.90	74.74
3d rep.	190.84	214.92	296.93	155.26	108.87
Treatment and replication	Period				
	11	12	13	14	15
DS					
1st rep.	146.87	145.31	110.77	163.21	136.01
2nd rep.	180.53	134.56	84.41	185.76	173.09
3d rep.	475.69	346.83	369.26	199.72	143.47
4th rep.	49.27	100.97	68.92	118.25	55.64
5th rep.	66.04	49.52	61.94	73.37	94.61
6th rep.	218.29	274.06	291.67	163.36	306.07
DS/DI					
1st rep.	214.89	150.47	164.87	534.29	158.45
2nd rep.	37.09	49.73	60.99	37.24	19.44
3d rep.	699.50	680.00	508.66	501.81	313.50
4th rep.	160.27	224.87	239.63	270.12	207.76
5th rep.	347.13	214.55	227.02	115.98	142.00
6th rep.	211.93	108.53	346.29	362.38	58.50
DS/CI					
1st rep.	309.83	229.24	165.60	83.12	36.26
2nd rep.	142.36	189.21	151.84	266.20	168.42
DS/TP					
1st rep.	61.96	57.43	90.0	77.12	82.81
2nd rep.	125.04	66.93	93.96	70.84	52.03
3d rep.	345.17	447.66	276.02	175.70	226.18

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